GENERAL MOTORS

Engineering JOURNAL

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PROGRESS IN VALVES

Thoughts on Automobile Styling

IN COMMON with the research worker and the engineer, the stylist makes himself both a leader and a follower by the exercise of common sense and imagination.

The stylist's real pride lies in the creativeness of his hands—hands which mold the offerings of a dreamer's mind into an automotive design which is aesthetically pleasing to the public.

By figuratively holding a wetted finger to the many winds of personal taste, the stylist detects the direction in which car owners of a coming year will look for beauty of line and design. He is a dreamer—but a practical one. He uses signposts of the past to guide into the future those features which have won public favor. Uniquely, he senses a theme and in developing it creates a trend.

Because he looks to and works for the years ahead, current modes of design are in the past to the stylist. Therefore, he remains ever alert to the fact that he is working in the *future* and that automobile styling must keep pace with progress. His work today must not run ahead of or lag behind the amount of change which the public will accept when his designs go into the market place.

In keeping abreast of the changing tides of influence of the automobile public, the stylist must constantly be ready to take into consideration any new trend. In recent years, for example, the women of the nation have become increasingly dominant in the selection of the family automobile. This trend has made it necessary for the stylist to become more and more cognizant of the feminine taste in both the interior and exterior design of the car.

To the research man and the engineer the stylist must look for the *purpose* of his work. Only after sound engineering quality has been assured for the engine and chassis of an automobile can the stylist honestly set himself to the task of applying beauty and grace of line to the car.

The automobile which reaches the public, then, is the product of teamwork—a vehicle which reflects the finest work of the research worker, the engineer, the stylist, and every other member of the team which gave it birth.

Harley J. Earl

Harley J. Earl,
Vice President in Charge
of Styling Staff

THE COVER

In the fifth of a cover series portraying transportation developments, Artist John Tabb illustrates the valves of internal-combustion engines. Valves are made according to a number of mechanical designs and material compositions to suit the requirements of a particular engine. Underlying these differences, however, is the basic requirement of all valves—the ability to perform in an atmosphere of very high temperatures. This quality is dependent upon the smooth functioning of valve-operating mechanisms. Improvements in mechanisms have relieved heavy shock loads on hot metal and have assured proper seating, hence proper cooling of valves at all thermal conditions of the engine. Economical, non-strategic valve materials also have resulted from continued metallurgical research.

CONTENTS

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The GENERAL MOTORS ENGINEERING JOURNAL is published every other month by the Educational Relations Section of the Department of Public Relations, General Motors Corporation, and is intended primarily as a medium for presenting to the field of engineering education the results of General Motors research and engineering developments both in the product and production fields.

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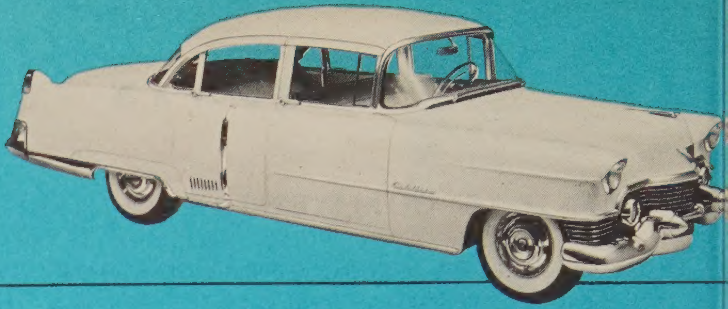
The Interrelationship of Styling and Basic Chassis Design

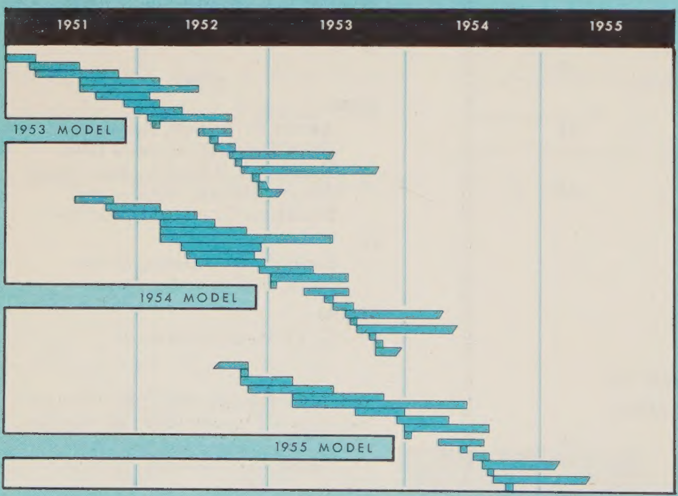


The design and styling of a new car model must take place long before the car reaches the customer. Prior to the actual-design stage, many features must have been developed and thoroughly tested before being considered for the new design. Possibly, some of the ideas may have been under development for longer than five or six years. Those features which can be incorporated into existing designs are released immediately as year-to-year car improvements. However, some features cannot be incorporated at once into year-to-year designs because of excessive tooling costs, space limitations, and other reasons. Development of these features continues, however, for use when major redesign is undertaken. Of particular interest to the engineers and automobile designers is the interrelationship of the design of the mechanical features and chassis with those of styling. The merits of styling may justify modifications of mechanical design and, conversely, the advantages of new features and chassis design may justify restyling considerations. While the 1952 Cadillac was being introduced to the public, engineers and designers already had well in mind the principal features of the models for 1954, a major redesign year.

In originating a new automobile model, stylists and engineers have equal contributions to make toward the development of a sound, salable product but often one area cannot be improved without affecting the other. Ideas for improving an automobile may be developed by engineers every day of the year, but improvements generally are not incorporated into the car until model-change-over time. Many improvements which have been previously developed and tested are incorporated into year-to-year model changes. Some improvements must be saved until a major redesign year, such as 1954 for the Cadillac, when incorporation of these improvements becomes possible and practical. To be worthy of consideration, new ideas must not only meet the many requirements of comfort, convenience, luxury, economy, performance, smoothness, and pleasing appearance, but also must fulfill the standards of safety, reliability, and durability. Much advance-planning time, therefore, is allotted to the design stage in the basic engineering schedule of a new model to provide adequate opportunity for adjustment and for integration of prime technical interests (Fig. 1).[1]

Factors which affect decisions on chassis and styling are:

- Preferences of the public; for example, comfort, performance, smoothness
- Improved design trends of which the public may not be aware; for example, safety features
- Improved production trends; for example, new methods of forming frames and new operations which enable greater manufacturing accuracy and efficiency.



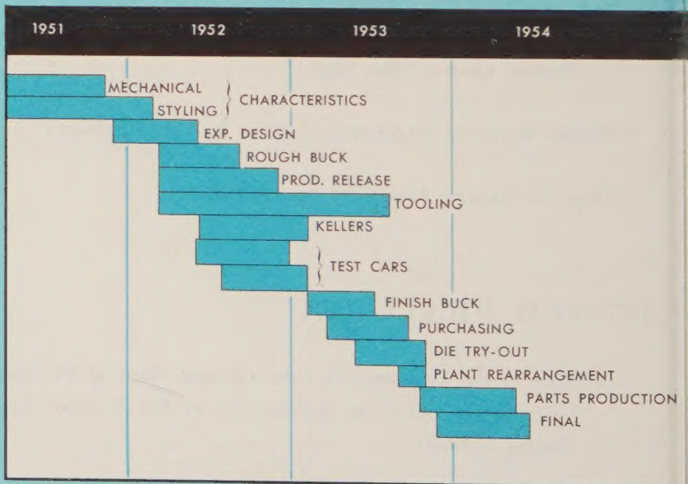


Fig. 1 (Left)—Chart illustrates a typical schedule for the design of a new model. Each of the overlapping horizontal bars represents a step or phase of the work. Note that, at any given time, three model years may be in the development stage. In this particular period, while production was well under way on the 1953 model, finishing touches were being put on the 1954 model and design features selected for the 1955 model. (Right) Chart illustrates breakdown of an engineering work schedule for the 1954 model year. Note that the mechanical and styling characteristics are finalized two years in advance.

By C. F. ARNOLD
Cadillac Motor Car Division

A chief engineer analyzes the technical task of designing a new model

Steps in the Evolution of a New Model

Design trends represent a step-by-step evolution toward a goal rather than merely annual mechanical changes. Producing a new car model is a process of assimilation and modification. In addition to improved features and styling, each design must attain the lowest tooling costs possible, it must both anticipate and solve future mechanical problems, and it must give engineering consideration to problems of shipping, handling, and packaging in order to obtain the maximum utilization of storage space. For each car model, engineering, manufacturing, and styling cooperate to confirm a design which is the best obtainable in its line at a reasonable price. Both the stylist and the engineer must be more discriminating than the customer.

The designing of a new car model begins with much give and take between the stylists and the design engineers. In turn, their decisions are affected by the guidance of many other areas of management. During this period, mechanical specifications are studied, changes are explained, wheelbase and important dimensions established, and the scope and limitations of the design program tentatively mapped out.

Once the basic styling theme has been agreed upon, much work remains to be done to bring it to its final form. The first sketches or *renderings*, as the more elaborate colored drawings are called, are made literally by the dozens, and then the best features of each are selected and combined into revised sketches. These selected designs are drawn full-size on large vertical boards to obtain true proportions (Fig. 2). This often shows up poor features. In one case involving a gull-wing bumper design, the original rendering looked very attractive but in actual scale the design proved impractical. Rechecks showed that, in order to preserve the original design proportions, both the hood and the cowl height would have to be dropped 6 in.—which was impractical.

The next step in the design phase is that of building the clay model in which the general proportions are worked out in three dimensions (Fig. 3). From this clay model, a plastic model is constructed in order that the highlights and flow-lines of the design can be studied and any errors corrected. (Depending upon the extent of redesign covered by the new car model, this plastic model may be a complete operating model with the actual finishing installed.) From this, tentative approval is made of the entire design by Divisional executives and engineers. All through this development period, many changes are being made to perfect all details, and many more modifications will be made as the new model approaches production.

Next come the experimental-development and cost-estimating stages, which must be undertaken together so that management knows exactly how much will have to be paid for each new feature. Wherever a body part, brace, panel, or piece of hardware can be made more simple in design and still perform its job well, the design engineer has the opportunity to reduce costs, lighten the tooling load, or minimize a production problem.

It is then customary to begin the production release of standard parts and those parts which will remain unchanged. At the same time, the first rough *buck* or *mock-up* of the parts is begun (Fig. 4). The tool engineers begin their preliminary work and about a month later the first *Keller models* are started. A Keller model is an actual-size wooden model of the body, fender, or hood panels, made to the exact contours of the finished part. The name Keller is derived from the *Keller Duplicating Machine* which reproduces on suitable pieces of metal, called die blocks, the intricate contours of the wooden die model. The resulting dies are used to stamp out the panels for the body or related sheet-metal assembly.

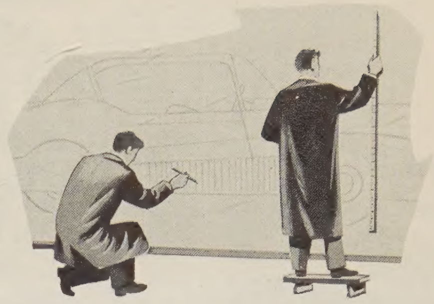


Fig. 2—Full-size drawings on large vertical boards are made of several designs to verify true proportions. Prior to this step, many other designs were rejected during the preliminary sketch stage.

Shortly afterward, the first complete test cars are built (Fig. 5). Prior to this stage, new features have been under development for years and have been individually tried out in experimental test cars. At this point, the tested components are brought together into the proposed prototypes to determine how well they work together. Many changes will have to be made to insure complete compatibility.

At this time, the finished mock-up is built from parts which are made exactly to release drawings. At this stage also, methods and equipment engineers and standards engineers, who have followed the progress of the model for many months, are called in to make their final studies to verify that manufacturing processes and facilities already planned are satisfactory. The Assembly Division also disassembles and reassembles the mock-up to train its supervisors and to verify

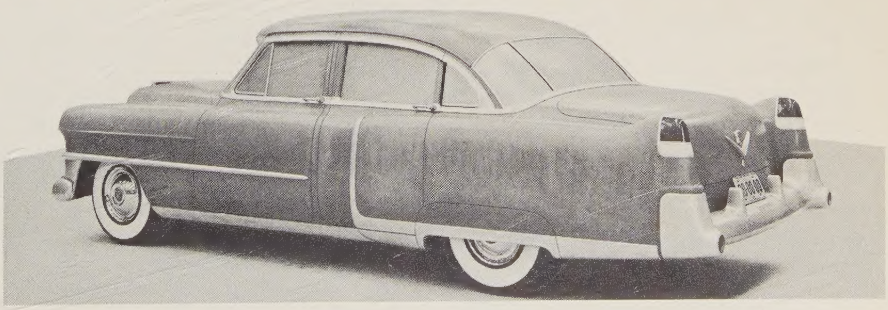


Fig. 3—A clay model is built to work out the general proportions of the new design.

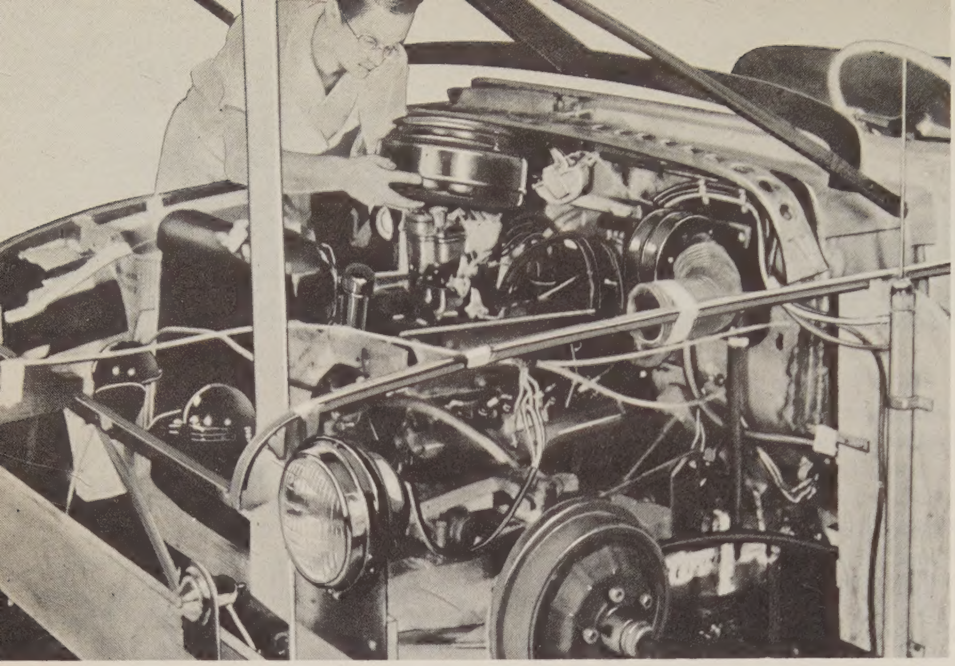


Fig. 4—First rough *buck* or *mock-up* which is made of the parts in the proposed design.

that the model can be assembled easily. The Service Department also studies the mock-up for service accessibility and gathers final information for service procedures. The changes resulting from these studies are the last stages in the actual design engineering, and the mock-up is followed very carefully since it really checks or proves the design.

Time, of course, must be allowed for the Purchasing Division to select sources for the tools and dies to be made and then tried out and corrected, if necessary, and for plant rearrangement for production of the new model. The production of component parts and the delivery of purchased parts then begins. Usually, about one month later, the first production car is built.

While all this is taking place, designers are thinking about cars which will be built three years later as well as working out the details of the two intervening models which are already well under way.

Problem Features

Experience during recent years has shown that invariably, where styling is ignored, a car, even though competitive from a mechanical standpoint, begins to slip in the market. It takes an expert to design a car to meet the legal dimensional limitations and predetermined company specifications, yet still provide maximum performance, reliability, and beauty. Both mechanical needs and human needs have to be satisfied in the final design.

Styling dictates, to some extent, what engineering must do. If the style trend is toward lower automobiles, the chassis engineers have to figure out how to get the frame down another inch. If there is to be more room inside the car without increasing the overall length, the engineers have the difficult task of finding the way to do it. However, sole responsibility for accomplishing this is not placed on the engineer; the stylist must also do his part by employing ingenuity in rearranging the interior to provide more room and using exterior design features which create the impression of length, width, and lowness.

The first two design stages, during which the mechanical and styling features are decided on and experimental development is begun, are naturally the most important. A great deal of compromise takes place in this period between styling and engineering. For example, the designer may have a grille design which, although beautiful, will not pass enough air for the radiator but if it is felt that the design has sales possibilities, a great deal of engineering effort may be exerted to find a solution to the cooling problem.

Not only does the stylist encounter problems with his new designs but the chassis designer may also design features which will result in poor styling. For example, the chassis designer may work out a very good suspension system but one which would require so much fender clearance that the resulting car would be high and old-fashioned looking. Or in the case of a new design which might eventually solve such problems as weight distribution on a rear-engined car, another problem still would remain of providing the car with good exterior proportions and good interior qualities without spoiling its appearance.

While these are theoretical examples, in actual practice there is much conflict in obtaining both beauty and functional qualities for many automotive components. For instance, the designer usually wishes to make fog lights small enough so that they are not obvious, while the electrical engineer desires a shape which will permit a reflector capable of giving maximum light. The wheel disc is another feature which creates design controversy. Many pro-

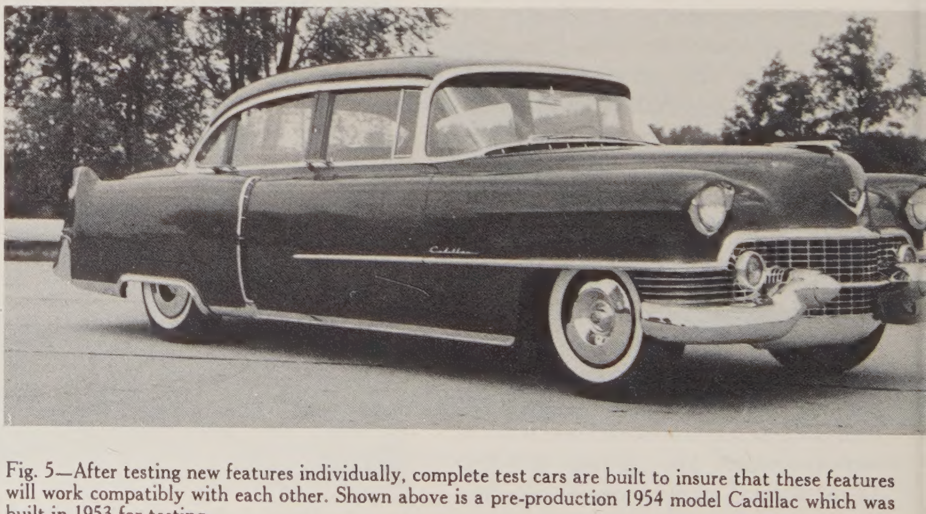
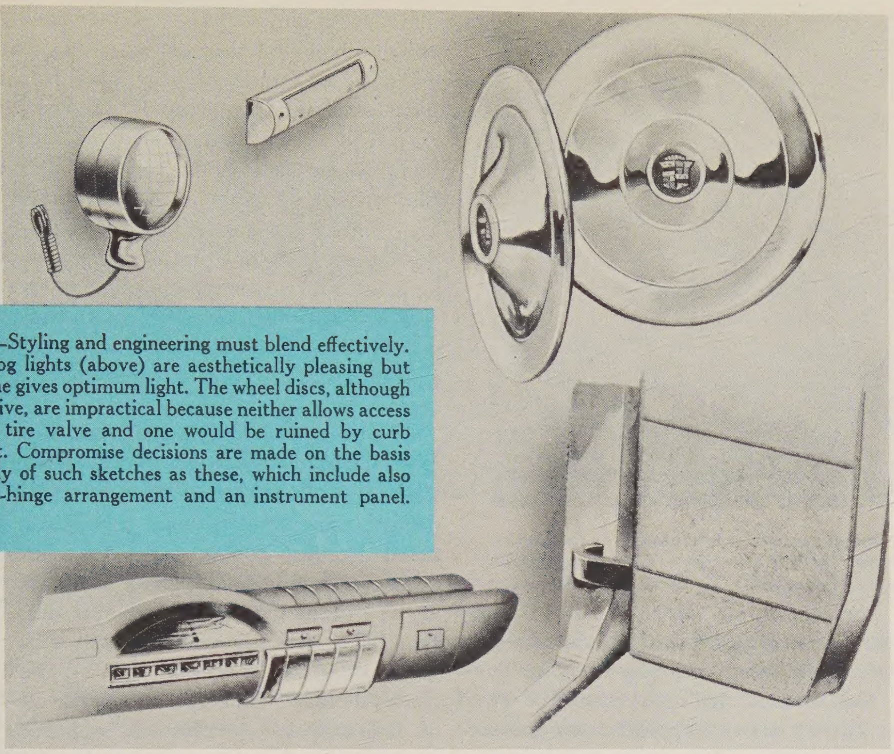


Fig. 5—After testing new features individually, complete test cars are built to insure that these features will work compatibly with each other. Shown above is a pre-production 1954 model Cadillac which was built in 1953 for testing.



5—Styling and engineering must blend effectively.
fog lights (above) are aesthetically pleasing but
one gives optimum light. The wheel discs, although
ctive, are impractical because neither allows access
ie tire valve and one would be ruined by curb
act. Compromise decisions are made on the basis
udy of such sketches as these, which include also
or-hinge arrangement and an instrument panel.

posed designs either would not permit access to the tire valve, would project in such a manner that the disc would be ruined by the first contact with the curb, or could not be made on a conventional press (Fig. 6).

Door hinging involves a basic design decision between styling and engineering as to whether or not the edge of the door should swing into the fender or away from it, with all the pros and cons of service and assembly involved. Another, and not least, is the problem of instrument-panel design with all the attempts to combine both artistic and functional qualities.

Current and Past Design Trends (Mechanical)

One trend which seems fairly certain to continue is the steady increase in provisions for comfort and convenience. Actually, the pattern has been to incorporate the comforts of home into cars to make of them "living rooms on wheels."

First came heaters, which now have been developed into complete heating and ventilating systems, and then radios were introduced. Next, automobile bodies were widened and lengthened, giving more hip and shoulder room, more leg and foot room, and greater luggage space. Greater comfort has been provided by the use of foam rubber in the seats; visibility has been greatly increased —in fact, the passenger is now practically surrounded by safety glass, tinted at his option. Controls and instruments have been rearranged for ease of operation and maximum visibility by the driver (Fig. 7).

The most recent innovations are power steering and air conditioning.[2] The air-conditioning system developed and used on the Cadillac is based on an entirely new-design compressor which gives greater displacement per mile (or tons of refrigeration per 24 hr) than other systems previously developed. One very important feature of this new system is the introduction of fresh air into the car, preventing stale odors and permitting occupants to smoke without discomforting other passengers. Filters effectively remove all dust and pollen which may be in the air circulating in the car.

One of the factors in the development of this particular air-conditioning system for Cadillac was the physical limitation resulting from automobile styling considerations and the use of greater glass areas which necessitated more cooling capacity than was available in air-conditioning systems previously in use.

Introducing air conditioning in the Cadillac also created additional styling problems. In preliminary surveys, it was found that very diffused air distribution through ducts maintained interior coolness in the most comfortable fashion. For the production design, the most practical solution was determined to be ducts in the roof with controllable air outlets which would permit the delivery of blasts of cold air directly to the interior of the car while still permitting the changing of these outlets to spread the air more evenly.

The principal problem here was to provide an installation attractive in appearance which would permit the delivery of the air from the rear package shelf to the roof duct. The final design chosen used ducts concealed beneath the headlining with movable outlet grilles (Fig. 8).

Although most of these comfort features are basically mechanical, all have had, or will have, their effect on styling as they become built-in features of the modern automobile.

A current practical trend which may affect styling is the studied effort being made to reduce or eliminate the effect of

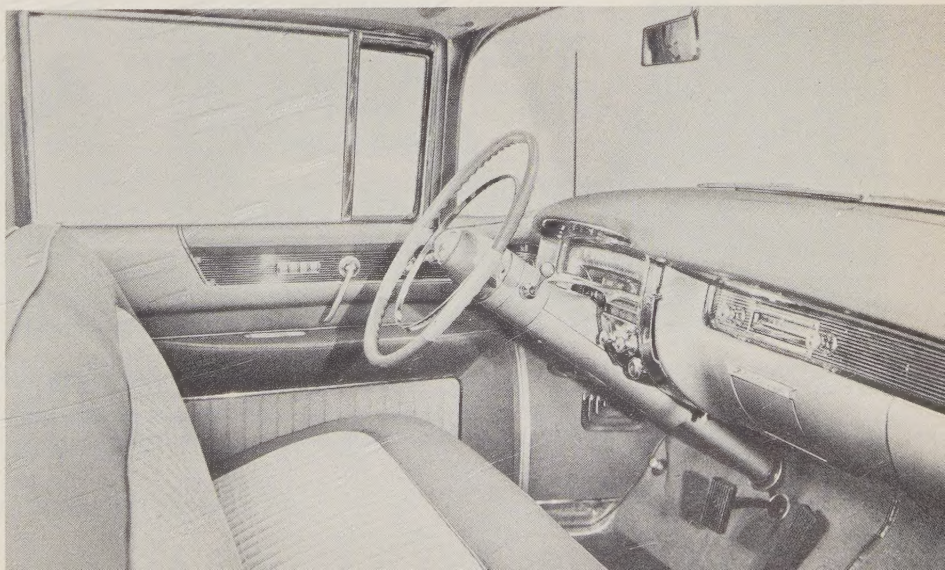


Fig. 7 (Right)—Current design trends provide maximum visibility with controls and instruments arranged for optimum ease of operation. The 1954 Cadillac's panoramic windshield, other windows, and the instrument panel are examples of these trends.

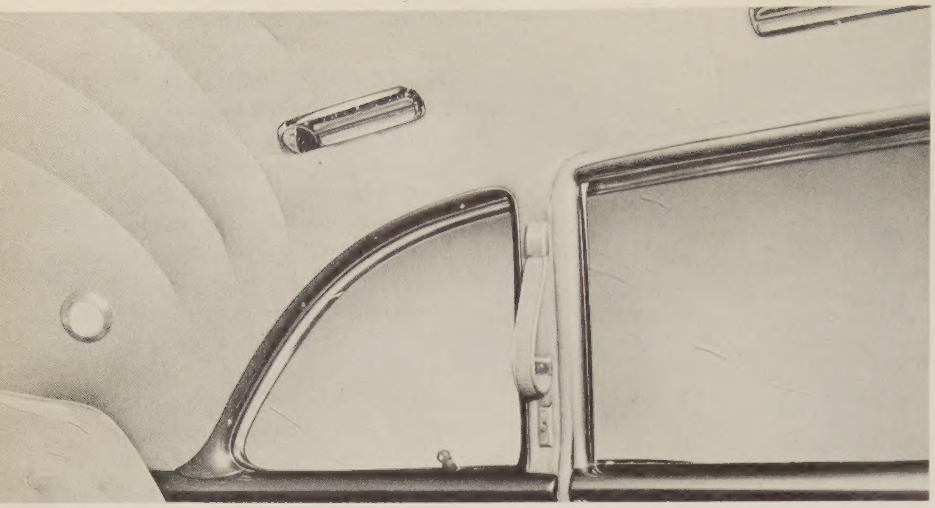


Fig. 8—In the design of the Cadillac air conditioner, a principal problem was to provide an installation for the diffusion of cold air to the interior of the car which would be both attractive and functional. Shown above is the new styling of the air-conditioning outlets in the 1954 model.

human error in manufacture and assembly. This is somewhat different from reducing human effort by motion study. For instance, in welding two parts together to form a T-shape, a fixture must be used which would require clearance to take parts of high limit. This clearance will allow the low-limit parts to shift out of position and result in the low-limit parts being included into an unsatisfactory relationship. However, if cone-shaped impressions were added to one part and matching holes to the other, they would naturally align themselves in the ideal position when pressed together. All that the operator would be required to do would be to place them together and they would automatically slide in the desired relationship (Fig. 9).

This example has been reduced to its simplest form but if applied to an entire door panel or cowl its requirement might easily affect the styling of the car. The advantages of such accurate construction would certainly justify some styling concessions. This problem of designing out the human error is becoming increasingly important everywhere to accomplish improvements in manufacturing techniques.

Current and Past Design Trends (Styling)

Certain basic principles have guided the development of the automobile to date and it may be expected that these will also be followed in the future. Typical styles over the past quarter century have employed rounded-off body corners, fender skirts, and the notched-back body during the 1930's, longer fenders blended into the body, lower roof curves and windshields, and increased glass area during the 1940's. Currently, the glass area has been increased to a point where it now completely surrounds the passengers. The car is still lower and the windshield is curved and formed in one piece.

This would point up the fact that automotive style changes are more evolutionary than revolutionary. There is a definite trend toward lower silhouettes, better blended curves, faster lines—in other words, the general effect of traveling at cruising speed while standing still. It is likely that this tendency will continue as a steady design trend. The chassis designer will be pressed to use all his ingenuity to lower frames, propeller shafts, and exhaust systems to the absolute limit. Cars will not, in all probability, become larger nor does it seem likely that they will become smaller. Although much has been written on the economic advantages of the very small car, the fact remains that, when the family wants to load up and go on a trip, there is no substitute for room. The average automobile owner will continue to drive to work in five times as much car as he may actually need in order to have the extra room when he does need it.

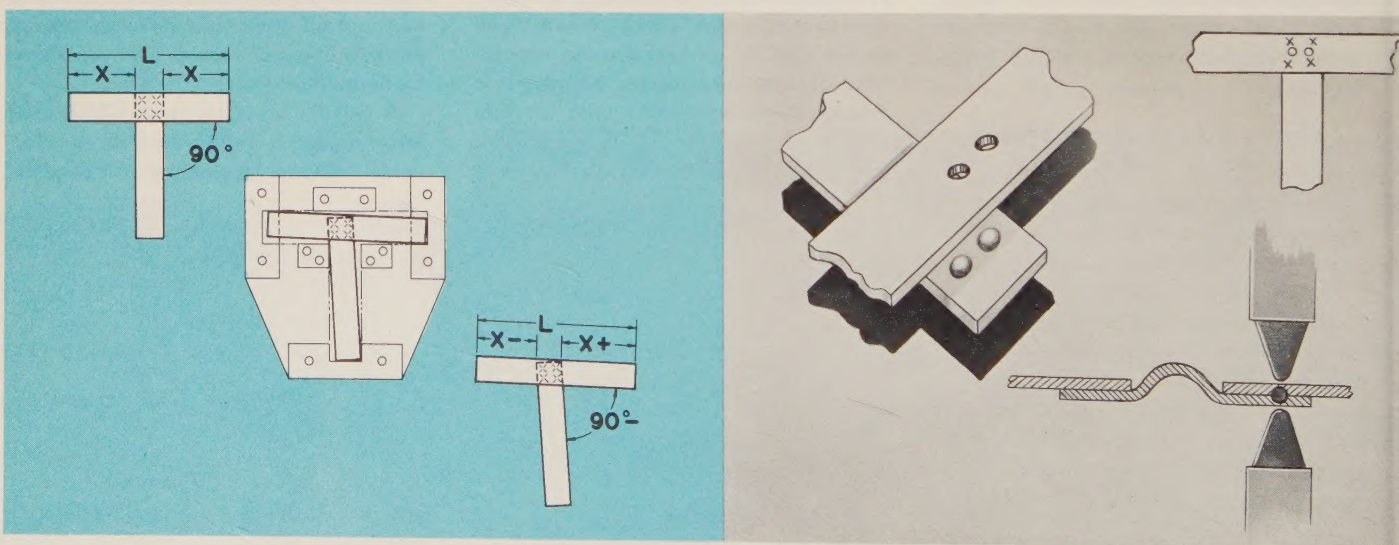


Fig. 9—Example of how design can reduce human effort and error in manufacture and assembly. (Left) The drawing shows how, in welding two parts together to form a T-shape, a fixture is needed which requires clearance to take parts of high limit. This permits the low-limit parts to be welded in the unsatisfactory relationship shown. (Right) The drawing illustrates how the welding accuracy is improved by adding cone-shaped impressions to one part and matching holes to the other so that they naturally align themselves in the ideal position when pressed together, thus reducing error and effort in the welding operation.

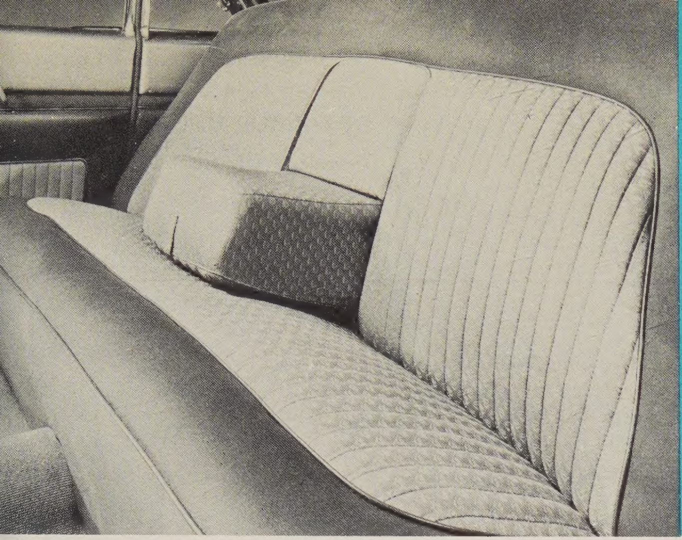


Fig. 10—A current design revolution is taking place in interior fittings, bringing them closer to the comfort, the conveniences, and the style appeal of the modern home.

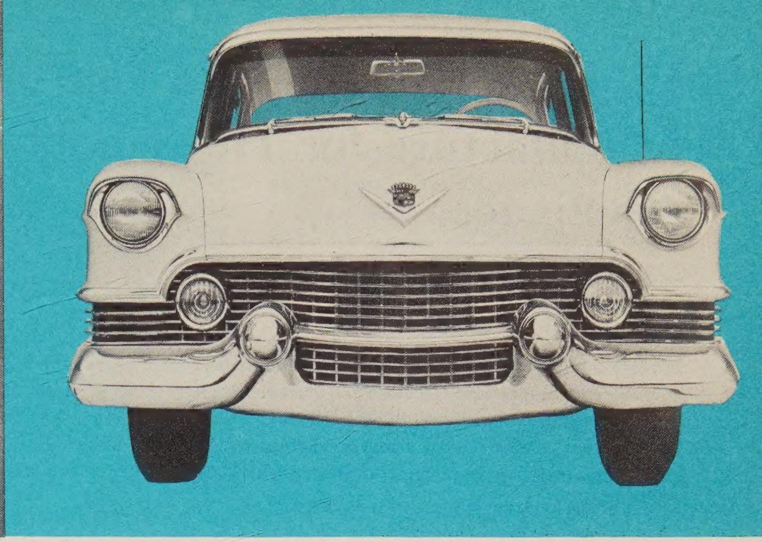


Fig. 11—Front view of this year's Special Fleetwood Sedan model Cadillac with its increased glass area—achieved by the panoramic windshield—lower body, new grille and bumper assembly, optional air conditioning, and other advanced design features.

However, while size may not increase, there will be changes made to make better use of the overall dimensions of today.

One of the most noteworthy current style trends is that involving interior fittings of all kinds which show the effects of a design revolution. This trend is another way of providing a model changeover with the added advantage that changing interiors annually is less expensive than changing the entire model. This trend is typical of the model changes which occur as a result of natural developments, for the use of color and fabric in modern living has been carried over from the home to the car (Fig. 10).

With the introduction of its 1954 model in January, the Cadillac Motor Car Division typified this forward-thinking aspect of design. Again, increased glass area, air conditioning, and other advanced design features were incorporated in the new models (Fig. 11).

Actual appearance details of future cars are unpredictable for they are the ideas and inspired designs that capture the public's fancy and encourage imitative competition. In 1934, the high, narrow grille and the airplane-wheel skirt fenders set the style, and then in the late 1930's the sharp, boat-prow front end came into vogue. Now the low, wide grille, introduced just before World War II and reminiscent of European race cars, is holding public attention.

Today's styles have adopted the characteristic features of fast-moving vehicles. The race-car carburetor air scoop has been adopted by several car manufacturers. The jet air-intake has been simulated on both rear fenders and, in some cases, on the front ends. The new windshields have the fast, clean lines of aircraft and even the exhausts are given a functional look.

Conclusion

Teamwork in the various stages of designing, engineering, cost estimating, tooling, fabricating, and assembling of a new car model combines engineering science with artistic skill. The design criteria of the engineers determine, in addition to pure styling and beauty of line, whether a design will:

- Lend itself to effective and low-cost tooling and processing
- Reduce to the absolute minimum human errors on the assembly line
- Stand up under the life expectancy of the car without undue replacement and repair.

It would seem that two definite trends appear in today's styling. Outwardly, there is the lower silhouette with its faster lines, smoother curves, and the occasionally inspired unique styling features. Inwardly, there are the appearance changes resulting from provisions for greater comfort which means not only seating facilities but heating and ventilating systems, visibility, ease of control, quietness, and safety.

The contribution of the stylist adds the final touch which means the difference between a design which is pleasing to the customer and a car which has no buyer appeal. He should provide individuality without eccentricity and his visions of today must attain the practicality of tomorrow.

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Porcelain Enamel: Its Use and Manufacture for Household Appliances

By WILBUR H. PFEIFFER
Frigidaire Division

Porcelain enamel is one of the finishes used for the steel parts which comprise household-appliance cabinets and structures. Porcelain enamel is a glass coating fused by an intricate process onto metal at high temperatures. Being glass, it offers permanent beauty, ease of care, and lasting protection to the metal under the heat, cold, moisture, grease, wear, and chemical conditions which occur during the use of the appliances.

The intriguing technical problems of glass on metal

PORCELAIN enamel is a glass coating on metal. Porcelain enamel and paint enamels are the commonly used finishes for the steel parts in household-appliance cabinets and structures. While these finishes are used extensively, relatively few people can distinguish between the two and the nature of porcelain enamel is not widely understood. Moreover, there is little in the technical literature which describes the nature of porcelain enamel and its suitability for various household appliances and correlates these to the complex procedure of applying it to the appliance parts.

The Identification of Porcelain Enamel

Vitreous enamel was the early name for porcelain enamel and it is quite descriptive since *vitreous* means glassy and *enamel* signifies a glossy coating on a base material. The term *porcelain enamel* signifies that the enamel is porcelain-like, that is, similar to true porcelain. True porcelain is the finest white earthenware which is sufficiently glassy to appear to be glazed and it is often called Chinese Porcelain or China because of its origin.

Similar in appearance to porcelain enamel is the glazed earthenware which is found in water-closet bowls and tanks and in older wall tile and often is called porcelain, China, or vitreous ware. Also similar in appearance is the paint-type enamel which usually comes to mind when the term enamel is used alone.

Examples of porcelain enamel uses in the home are telephone dials, the white or colored panels on the front and the top of the kitchen range, the blue-black oven lining of the range, and the white or colored lining in the refrigerator. Articles such as these are almost always made of porcelain-enameled sheet steel. Most of the sinks, bathtubs, and water closets are porcelain-enameled cast iron although some may be earthenware. In recent years many of these have been made of porcelain-enameled sheet steel. Porcelain enamel also may be seen on some store fronts, small homes, small restaurant buildings, gasoline pumps, and advertising and direction signs.

The Origin and Development of Porcelain Enameling

Historians believe that the early Egyptians did porcelain enameling by fusing glass into cavities in metal objects. By the sixth century some characteristic methods were devised for creating such cavities in the noble and copper metals and this art flourished, especially in Byzantium. After the twelfth century the art had grown and spread in Europe and it was there, in the sixteenth century, that the art was developed whereby the enamel was painted onto a metal surface and later fused into place. All of these methods are in use today for art and jewelry-making purposes.

Dry Process

The enameling of iron was done in Europe early in the nineteenth century. Cast iron was heated to redness in a furnace and, after withdrawing the iron from the furnace, powdered glass was dusted on the metal where it partially fused. The piece then was returned to the furnace to complete the fusing process. Early industrial uses of the process were found in the production of cooking utensils, and later it found application in the manufacture of plumbing ware. Known as the *dry process*, it has been used for many purposes including the processing of most of the bathtubs, lavatories, and sinks made during the first half of the present century.

Wet Process

An alternate method of enameling sheet iron began in Europe about a century ago and was first applied commercially to cooking utensils. In this enameling process the powdered glass was suspended in a mixture of water and clay and application of the mixture to the metal was accomplished by the action of dipping or pouring. In later years a spray-application method was developed. After drying, the piece was put into a furnace to fuse the enamel. This method became known as the *wet process*.

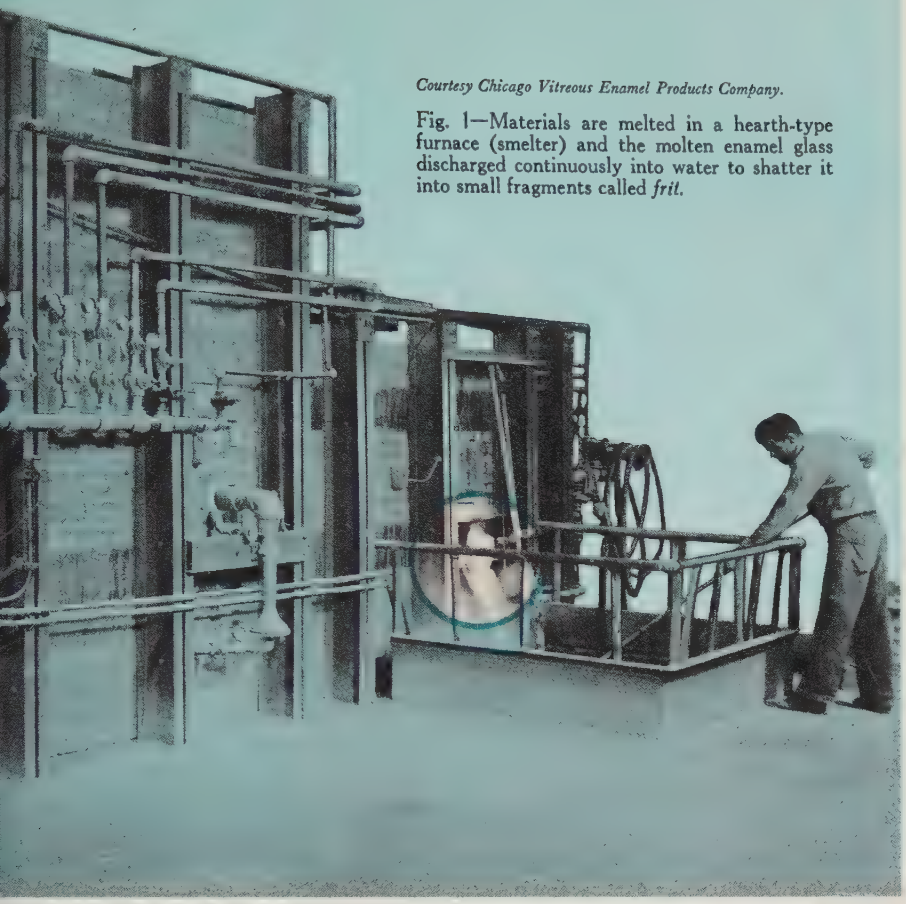
One method of obtaining adherence of the enamel to the metal resulted in a mottled-gray enamel. This was used until recent years for cooking utensils and products using this finish often were called granite or agate ware. Later, it was learned that cobalt oxide could be added to the glass to promote adherence. The cobalt gave the enamel a blue color; however, a second coat of different colored enamel, such as white, could be applied to cover the blue color. The first coat became known as a *ground coat* and the second coat as a *cover coat*.

This method of enameling is so versatile that it now has the greatest number of uses for all kinds of parts and products.

The commercial enameling of aluminum is recent. It is done by the wet process and is used chiefly for architectural and industrial purposes.

The Characteristics of the Appliance Finishes

The parts which make up household appliances are fabricated from sheet steel



Courtesy Chicago Vitreous Enamel Products Company.

Fig. 1—Materials are melted in a hearth-type furnace (smelter) and the molten enamel glass discharged continuously into water to shatter it into small fragments called *frit.*

and must be finished to protect them from corrosion and to give them a pleasing appearance. Porcelain enamel and baked paint enamels are the commonly used finishes. They are similar in appearance but each has its own merits in cost, protection of the metal, and permanence.

Porcelain Enamel

Since porcelain enamel is glass it acts as an impervious barrier protecting the steel completely unless it is disrupted in some manner. Chemical attack causes little trouble because enamel glasses of appropriate resistance are chosen to meet specific needs. The enamel surface can be scratched and abraded, however, by very hard materials and the repeated formation of ice can chip tiny flakes from the surface of some types of enamels.

Like all glasses, porcelain enamel is brittle and can be fractured by excessive distortion. After fracture occurs, the enamel cannot be restored. The remedy is to cover the damaged area with paint-type materials.

Except under the conditions mentioned above, porcelain enamel does not change with the passing years and requires only a simple washing to keep it clean.

Paint Enamel

Paint enamels are not impervious; consequently, their protection of the steel is a matter of degree or circumstance. If paint enamels are given regular care and not subjected to extreme conditions, they provide satisfactory protection.

Moisture migrates in and out of the paint film and if prevailing conditions cause prolonged saturation the moisture can be harmful. This is especially true when soluble salts are a part of the saturating water such as in salt mist at the seacoast or in detergents which contain alkalis.

Paint enamels are organic materials and they can be marred, scratched, abraded, or cut through. They can be damaged by heat and, in the few cases tested, they were damaged by the repeated formation of ice. They suffer some change as they age and this is manifested especially by a yellowing of the color. The absorption of grease fumes hastens this discoloration and tends to soften paint enamels. They are stained by some rubbers, foods, inks, and other materials found in the household. They must be cleaned and polished periodically as a part of good care but when they are damaged they can be repaired satisfactorily by sanding the damaged area and spraying on an air-dry-type of enamel.

The Household Appliances

The household appliances are used for various services and under various conditions. It is helpful to examine these conditions as an aid in comparing the properties of paint enamel and porcelain enamel. From such a study, the merits of porcelain enamel also can be clearly seen, together with the importance of the manufacturing process.

Kitchen Ranges

Porcelain enamel has been the common finish for kitchen ranges for many years because it withstands heat, grease, and spilled foods. Furthermore, the suitability of porcelain enamel has been so well established that few other finishes have been attempted. On kitchen ranges, the ordinary types of porcelain enamels are used except for the top panel where the enamel is selected that has the best resistance to acids and to scratching. This appliance is a good example of how the blue-black ground coat is satisfactory in itself for the oven lining and other interior parts and how a cover coat is applied over the ground coat on exterior parts to obtain whiteness or color and a glossy surface.

Refrigerators

The exteriors of most refrigerators have a paint-enamel finish which has proved satisfactory in most cases. In climates where the humidity and temperature are high, such as the southern seacoast, condensation of moisture is a problem because the refrigerator is always colder than the surrounding atmosphere. Where considerable frying is done in the same room with the refrigerator and ventilation is poor, grease fumes condense on the refrigerator. In cases such as these and where permanent beauty and ease of care are sought, the extra cost of porcelain enamel is worth-while. The ordinary types of porcelain enamel are used for this purpose.

Most refrigerator linings and probably all of the steel vegetable pans are finished with porcelain enamel to accommodate

the special requirements of refrigerator interiors. In some refrigerators ice may, at times, alternately form and thaw on the surface of the lining and some refrigerators have compartments which are always at high humidity. There is also the hazard of abrasion and cutting by the objects stored in the refrigerator. Porcelain enamels which are not harmed by repeated ice formation and which have good resistance to acids are used for these purposes.

Home-Laundry Appliances

In the home-laundry appliances, washing-machine tubs usually are porcelain enameled and for this purpose the enamel must have high resistance to the synthetic detergents, especially those which contain any of the polyphosphates. Some dryer drums are porcelain enameled which provides, at low cost, the characteristics of smooth surface and moisture resistance. Many washing-machine and dryer cabinets are finished with paint enamels and, until the advent of a number of recent paint developments, resistance to detergents was somewhat of a problem.

Moisture resistance especially is a problem, not only because of the use of hot water and the presence of moisture in the operation of the home-laundry appliances, but also because many of these appliances are located in basements which are damp. Some washer and dryer cabinets are porcelain enameled. The only special requirements of finishes for home-laundry appliances are that certain parts have a high resistance to the harmful chemicals in some detergents and that the top panels have reasonable acid- and abrasion-resistance.

Water-Heater Tanks

Galvanized steel has been the common material for water-heater tanks but it has a limited and sometimes short life due to the corrosive nature of water under pressure and at elevated temperatures. Special metals have been used but the trend is to porcelain-enameled tanks (also called glass-lined tanks) which, because of the special enamels used, are suitable for both hard and soft water.

The Porcelain Enameling of Appliance Parts

Of the two enameling processes described, only the wet process for enameling sheet-steel parts is considered herein since the enameling of all major household appliances is done by this process.

The Steel Parts

The parts for household appliances are formed from steel sheets which are usually 17 gage to 24 gage (0.0538 in. to 0.0239 in. thick). Several grades may be used.

In common use is a grade of sheet called *enameling iron*. It is given this term because the sheets are processed at the steel mill especially for porcelain enameling and because of the high purity of the iron (0.01 per cent to 0.04 per cent carbon, not more than 0.1 per cent manganese plus a minimum of residuals) although there are some exceptions for specific purposes. These sheets have uniformly good strength at high temperatures, cause a minimum of defects in the enamel, and have a special surface texture which is desired for easy application and good adherence of the enamel.

Low-carbon steel sheets (0.05 per cent to 0.08 per cent carbon, 0.25 per cent to 0.50 per cent manganese plus residuals) such as are used for automobile bodies are used to some extent. They are of low cost but because of their composition and the steel-mill processing they have poor strength at high temperatures and tend to have internal and surface conditions which cause defects in the enamel coating.

Parts are often welded together into assemblies and after fabrication they are cleaned by specialized chemical means to remove contaminants, rust, and welding scale in preparation for enameling.

The Enamel Glass (Frit)

The difference in characteristics of various porcelain enamels is determined by the enamel glass. No single type of glass can incorporate all of the needed qualities; consequently, several types of glass are used. These various types of glasses are developed and manufactured by specialists in the industry to meet the needs of the manufacturers of porcelain-enameled products.

The principal glass-forming materials are silica sand, feldspar, borax, fluorspar, cryolite, sodium silicofluoride, alumina, zinc oxide, soda ash, sodium nitrate, barium carbonate, and lithium carbonate. Combinations of some of these materials are used to produce clear, colorless glasses while in other cases coloring materials are added to produce darkly colored enamels. To still other combinations cobalt, nickel, and manganese oxides are added for ground-coat enamels, and antimony, zirconium, or titanium oxides may be added for white cover-coat enamels. The commercially used compositions are not published but probably silica, borax, and feldspar comprise three-fourths of the compositions of all of the enamels except the zirconium and titanium types, which are peculiar

Only the titanium-type of white enamel will be considered herein because it is the

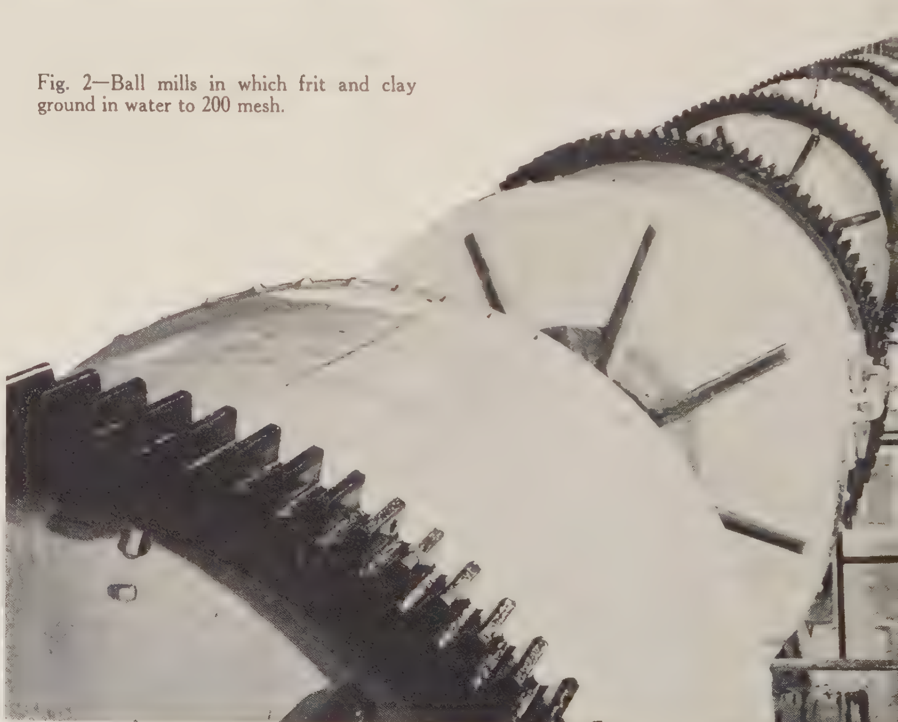


Fig. 2—Ball mills in which frit and clay ground in water to 200 mesh.

Fig. 3—Applying ground-coat enamel to a refrigerator lining by dipping.

type in common use for household appliances.

To form the glass, the selected ingredients are mixed and then *smelted*, that is, melted in a hearth-type furnace at temperatures above 2,000° F. After the smelting is completed the molten glass is permitted to run from the furnace and be quenched by water or water-cooled rolls which shatters the glass into small fragments (Fig. 1). The shattered glass is called *frit*.

Enamel Requirements

The first requirement of an enamel is that it should form a smooth, continuous coating which adheres well to the base metal. With the exception of certain special processes not yet in common use, this requirement is met by the incorporation of cobalt, nickel, and manganese oxides into the frit to promote adherence. These compounds cause the enamel to have a blue-black color.

Good fluidity of the enamel while it is being fused onto the metal is necessary to permit the escape of gases from the reactions and this occurrence has some effect on surface texture. Because of its color and surface texture this ground-coat-type of enamel is suitable in itself for only certain purposes. However, it is satisfactory as a base over which a finish or cover-coat enamel is applied.

Since the cover-coat enamels do not need the fluidity and adherence properties of the ground coats, their compositions can be adjusted to give a variety of appearances and physical and chemical properties. When titanium dioxide is a part of the frit composition, it causes the enamel to be white by crystallization during the fusion of the enamel. Colors are produced by adding colorants in the preparation of the enamel using white, clear, or colored frit depending upon the shade of color desired.

The Application of the Enamels

The enamel is prepared by mixing the frit with water and relatively small amounts of clay and chemicals in a *ball mill* and grinding until almost all of the mixture passes through a 200-mesh screen (Fig. 2). The successful application of the enamel is dependent upon certain qualities of the clays which are used. The clays must hold the frit particles in suspension in the water until application to the steel is accomplished and they must hold the enamel coating on the parts until the enamel is fused. The clays also must go into solution in the enamel glass during fusion without discoloration or other harmful effects.

Ground Coat

In almost all cases the ground coat is applied to both sides of the parts whereas the cover coat is applied to one side only. Consequently, the ground coat usually is applied by dipping and the cover coat by spraying (Figs. 3 and 4). The ground coat may be sprayed, however, when the parts are unsuitable for dipping, and often the cover coat is dipped on some parts such as refrigerator vegetable pans where both sides are to be coated. The parts finally are passed through an oven on a conveyor for drying.

Each coat of enamel is fired or fused separately by passing the parts through an air-atmosphere furnace. The parts are hung from a monorail conveyor for this purpose (Fig. 5). The parts are in the hot zone of the furnace usually from three to four minutes at about 1,500° F to fire the ground coat and from two to three minutes at the same or usually a 20° F to 50° F lower temperature to fire the cover coat.

The Enamel-Metal System

When the ground coat is applied to the metal, the part is put into the furnace and these events occur in sequence:

(a) The metal surface oxidizes as the parts are heated.
(b) The clay and some of the chemicals dehydrate.
(c) The metal and the glass give off gases.
(d) Hydrogen is absorbed by the metal.
(e) The melted glass dissolves the iron oxide, the clay, and the chemicals.
(f) The melted glass wets the metal.
(g) The dissolved iron oxide and the bubbles migrate through the molten enamel.
(h) Stresses in the metal are relieved and the metal distorts because of differential heating and the pull of gravity.

Fig. 4—Applying white cover-coat enamel to refrigerator cabinets by spraying.

As the parts cool the glass re-absorbs gases and solidifies, stresses and strains develop because of differential cooling and because of the differential contraction between the metal and the enamel, and hydrogen becomes less soluble in the iron which causes it to develop pressures that tend to force the enamel away from the metal surface.

The events in the firing of the ground coat make it apparent that good fluidity of the glass is necessary to dispose of the gases formed and it is an established fact that molten ground-coat glasses are true liquids. It is also apparent that the glass must have a great capacity to dissolve iron oxide. The cobalt, nickel, and manganese oxides promote adherence by providing oxygen continuously and perhaps for other reasons not well understood.

All portions of the enamel-metal system must reach and hold a satisfactory temperature for a minimum time in order to insure proper progress of the reactions. Increasing the temperature or the time causes excessive reactions and destruction of the glassy nature of the enamel and the adherence of the enamel to the metal. The melting-temperature range of the frit must be kept low because of the distortion of the metal which increases rapidly as the temperature approaches the upper critical values for iron or steel (1,653° F for pure iron and 100° F to 200° F lower for steel).

The degree of adherence of the enamel to the metal is critical in that it must be sufficient to resist the *hydrogen pressure* which develops in the metal. At any point where the adherence is insufficient, the hydrogen pressure disrupts the enamel coating in a circular area. The stresses present then cause the enamel to fracture in a half-moon way, resulting in a fishscale appearance. For this reason, the defect is called a *fishscale*. Fishscaling may not occur for several weeks after the metal is enameled as some time is required for the hydrogen to develop its maximum pressure.

Cover Coat

The events in the firing of the cover-coat enamel are relatively simple. It fuses readily to the ground coat so adherence is not a problem. Dehydration of the clay and chemicals and gases rising from the ground coat create the need for some fluidity. This is somewhat of a problem because as the titanium compounds crystallize in the molten glass they cause it to become a non-Newtonian liquid. The time and temperature must be sufficient to dissolve the clay and chemicals, dispose of gases, develop a smooth surface, and permit the titanium compounds to crystallize or the colorants to reach the correct condition. However, the time and temperature must not be sufficient to cause excessive activity in the ground coat, solution of the colorants, or precipitation of the titanium-dioxide crystallites in an unfavorable form. Titanium dioxide is the most effective whitener (opacifier) known for porcelain enamel but its effectiveness depends upon proper crystallization from the glass as has been discussed extensively by Cole.[1] He states that composition of the glass, temperature, time, and viscosity must be such that the crystallites will be wholly or predominately of the anatase form instead of the rutile form and that they will be of optimum size if the best reflectance and color are to be obtained. He points out (a) that the spectral reflectance of rutile is very low at wavelengths below 420 microns which causes it to have a yellow tone and (b) that crystallite particle sizes of 0.16 microns to 0.18 microns are of a blue tone, those of 0.32 microns and 0.45 microns are of a yellow tone, and those 0.20 microns and 0.25 microns are nearly neutral (achromatic). He further states that high temperature favors the formation of rutile and that both high temperatures and long reaction time are probably favorable to coagulation of the crystallites.

Another item of critical importance in the enamel-metal system comes from the fact that glasses are very strong in compression but weak in tension. Consequently, the frit compositions are selected so that the enamel will contract less than the metal during cooling leaving the enamel in a state of compression. When a strain is imposed thereafter it either creates more compression or it is absorbed in relieving compression so that failure does not result unless the strain is excessive.

Other factors which have an important effect upon the resistance of the enamel-metal system to damage are the thickness of the base metal and the thickness of the enamel. Mechanical damage of the enamel rarely occurs without some permanent deformation of the metal; therefore, it is obvious that thicker metal offers increased resistance. Failure of the enamel from impact starts from tension within the enamel glass near the metal

surface; thus, a thick enamel increases the resistance to this kind of damage. However, the situation is different for bending and torsion where the failure starts at the surface of the enamel from tension. Thinner enamel is more resistant in this case because the surface of the enamel is closer to the neutral axis and greater distortion is required to produce sufficient tension to start failure. Since appliance parts are subjected much more to bending and torsion than to impact, thin enamel coatings are sought.

The enamel and metal thicknesses have little effect upon resistance to thermal damage which is more closely related to the inherent stresses in the enamel.

The ground-coat enamel thickness necessitated by the application and firing is usually 0.003 in. to 0.0045 in. and for special conditions 0.0025 in. to 0.006 in. Usually, the minimum thickness of the enamel is less than 0.003 in. as it is difficult to apply cover-coat enamel at less than this thickness and obtain a smooth surface and good appearance. For satisfactory appearance the white enamel on the exterior of household appliances must reflect at least 75 per cent of all of the visible light it receives (diffuse reflectance) but on interior parts the reflectance may be as low at 70 per cent or even 65 per cent. With the titanium-type of frit these requirements can be met with 0.0025 in. to 0.005 in. thickness.

Technical Progress

Twenty-five years ago the porcelain enameling of sheet steel was still a practical art and knowledge was largely a matter of trade secrets. Only small parts could be enameled and major interruptions of production by trouble in the process were common. White enamels were applied in two coats over the ground coat with a minimum total thickness of 0.014 in. required for satisfactory appearance. The resistance to chemical attack was poor.

Through progressive technical studies the whole character of the industry has been changed. Complete structures, such as the outer cabinets for refrigerators which are fabricated by joining many pieces, are enameled and interruptions of production are rare. White enamels are applied in one coat over the ground coat with a minimum total thickness of 0.006 in. required for satisfactory appearance. The allowable degree of resistance to chemical attack is largely a matter of choice. Much effort is being devoted to the development of processes for applying white enamel directly to the metal without the use of a ground coat and also to the improvement of the present process to lower the temperatures required and to eliminate variations in the results.

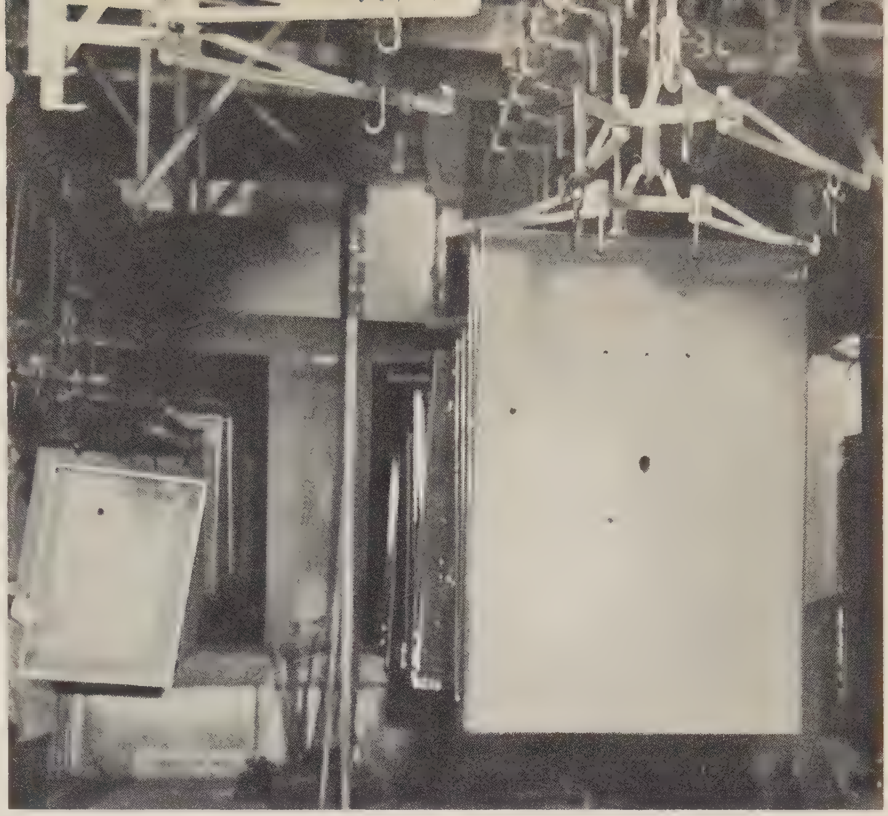


Fig. 5—Refrigerator linings hanging from fixtures enter (left) and leave (right) U-type furnace (background) where the ground-coat enamel is fused.

Conclusion

Porcelain enamel is a glass coating on metal and when it is applied to parts fabricated from sheet steel is a superior finish for major household appliances. Like all glasses it is brittle and subject to fracture by abuse but its wide use establishes that this is not an unreasonable hazard. Like all glasses there is no means of restoring it when fractured but a paint-type repair can be made.

The requirement that the enamel glass be bonded to the metal in a smooth enamel coating necessitates the use of several kinds of enamel glass and results in a difficult manufacturing process of rather high cost. However, satisfactory properties and qualities can be obtained to meet the requirements of the major home appliances and constant progress is being made in improving the quality and reducing the cost.

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The Design, Development, and Manufacture of Hydraulic Valve Lifters

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Division

Hydraulic mechanisms control internal functions of engines

To the average automobile owner, the most apparent changes in engine design are those involving the engine model and its efficiency. Yet the complexity of engine components requires a constant evolution in the engine structure as well. With every new engine design, the normal problems of internal overall design are intensified. An example of such a condition is that involving the valve train of an engine—that portion of equipment which controls the opening and closing of the valves. The lash or clearance of valve-gear parts might be termed the "nerve center" of the engine since it is only by controlling this factor that the rapid changes in temperature and eventual wear in the engine system can be regulated. The development of hydraulic adjusting mechanisms or hydraulic valve lifters has achieved this controlled internal functioning through a means of automatic compensation for the thermal expansion and contraction of engine parts. The V-8 engine uses a total of 16 such hydraulic valve lifters—one for every valve in the engine. Thus, in each new engine design, careful and extensive checking of this vital component is necessary before it can be incorporated into the engine structure.

SINCE the invention of the first automotive engine, one of the principal engineering problems has been the controlling of the lash in the *valve train.* The valve train of an engine comprises those parts required to open and close the valves (Fig. 1). In an *L-head engine*—or an engine where the valves are in the block—the valve gear is made up of the valve, valve spring, valve-spring retainer, keepers, follower, and camshaft. In the *overhead-valve engine*—or valve-in-head engine—the valve gear is composed of the valve, valve spring, valve-spring retainer keepers, rocker arm, push rod, follower and camshaft. The *lash* of the valv gear, or valve lash as it is sometime called, is the clearance between thes valve-gear parts when the follower is o the base circle of the cam. Lash in th valve gear is required to permit expan sion of valve-gear parts and thus permit the valve to close when the lifter is on th base circle of the cam.

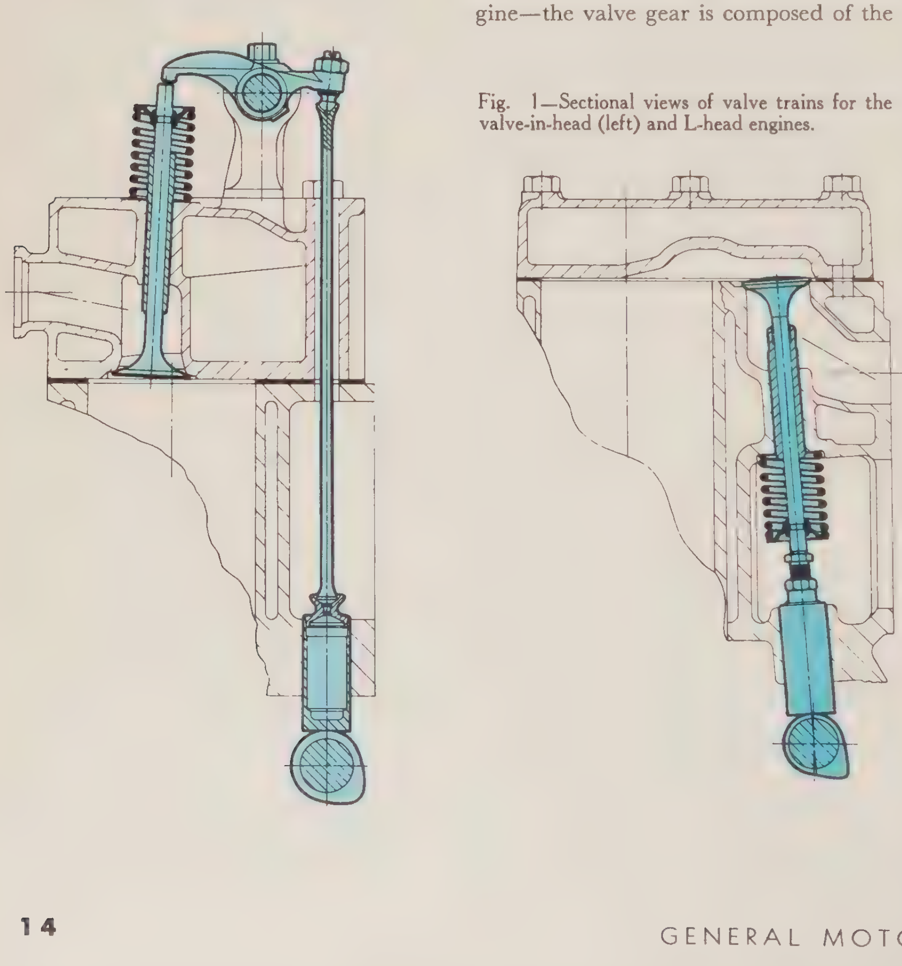
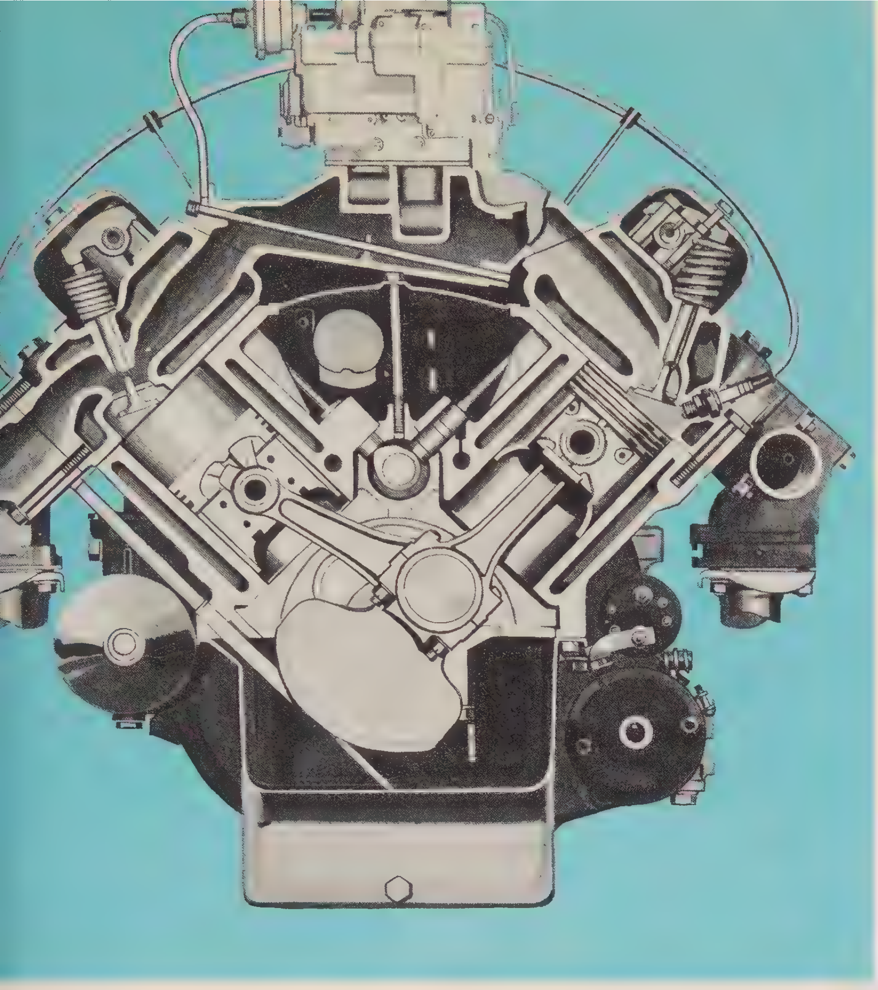


Fig. 1—Sectional views of valve trains for the valve-in-head (left) and L-head engines.

Historical Background

One of the first attempts to control th valve lash in an engine was made by a Frenchman, Amedee Bollee, who filed a patent in 1911 for a new type of valv gear to "regulate automatically the pla in the control of valves such as are use in explosion engines." This constitute the first patent covering a hydraulicall operated follower to control the lash Since that time, a great deal of experi menting and testing has been done t perfect a hydraulic-type of lash contro known today as the *hydraulic valve lifter*

Prior to the use of the hydraulic valv lifter, the usual means of controlling th lash in the L-head engine was by placin an adjusting screw in the follower. Thi adjusting screw was set to give a speci fied amount of clearance in the valv gear when the follower was on the bas circle of the cam. On the valve-in-hea engine, the adjusting screw was place in the push-rod end of the rocker arm Although several L-head engines use hydraulic valve lifters of one sort o another, it was the overhead-valve, in line, and V engines, that created th



ig. 2—Transverse section of a V-8 engine which uses a total of 16 hydraulic valve lifters. As shown on ie right cylinder bank, the lifter rides on the cam and is guided in a hole bored in the block of the igine and is connected to the rocker arm by a push rod. On the other side of the rocker arm are the valve, ılve spring, valve-spring retainer, and keepers.

reat demand for some type of automatic ıke-up device. Because of the greater istance from the camshaft to the valve ı the overhead-valve engine, the greater as the variation in the lash due to the ıermal expansion and contraction of the arts. The system also had less rigidity.)ne solution to the lash-adjustment roblem was to replace the follower and ıe adjusting screw with a hydraulic djusting mechanism which would acommodate the rapid changes in temerature and eventual wear in the system. he automotive engineer developed such device in the hydraulic valve lifter.

Hydraulic Valve Lifter

A V-8 engine employs a total of 16 ydraulic valve lifters—one for every ılve in the engine. Fig. 2 illustrates a ansverse section of a V-8 engine with e hydraulic valve lifter and the other mponents which constitute the valve gear. The hydraulic valve lifter rides on the cam and is guided in a hole bored in the block of the engine. The hydraulic valve-lifter motion is transmitted to the rocker arm by means of a push rod. On the other side of the rocker arm are shown the valve, valve spring, valve-spring retainer, and keepers. This discussion is primarily concerned with only one component of this valve gear and that is the hydraulic valve lifter.

Operational Advantages

The hydraulic valve lifter provides a simple and effective means of automatically maintaining all the components of the valve gear in contact at all times. In so doing, the hydraulic valve lifter offers five specific advantages in engine operation:

- Elimination of tappet-clearance noise
- Elimination of valve-clearance adjustments
- Longer valve life by elimination of pounding
- Smoother engine performance due to precise control of valve timing
- Automatic compensation for expansion and contraction of valve gear and engine structure caused by engine-temperature changes and differentials.

Hydraulic valve lifters consist of seven fundamental parts: the plunger retainer, the push-rod seat, plunger, ball check, ball retainer, spring, and the body or follower. Fig. 3 shows five models of hydraulic valve lifters.

Lubrication System

The engine lubrication system showing how oil is fed to the hydraulic valve lifters is illustrated in Fig. 4. This is a typical lubrication system for a V-8 engine. A gear-type oil pump is shown mounted on the rear main bearing cap. Oil enters the pump through an attached screened intake which floats on the oil and draws off only the clean oil from the surface. As the illustration shows, the oil taken in through the intake is forced by the pump through the rear bearing cap to the vertical oil passage. This vertical oil passage is intersected by the right oil passage and a connector which intersects with the left oil passage. The oil in the right and left passages flows to the lifters through small drilled holes connecting the passages with the lifter holes.

Functions and Procedure

To illustrate the operation of the hydraulic valve lifter, Fig. 5 shows the lifter in four cam positions. **Position 1** shows the lifter on the base circle of the cam. In this position, the spring in the lifter takes up all the clearance in the valve gear. At the same time the ball check is lying in the bottom of the ball retainer. The lifter receives oil under pressure from the engine lubricating system just described. This oil enters the lifter body through the body-feed holes and flows into the inside of the plunger through the holes in the side of the plunger. The oil continues to flow down through the hole in the bottom of the plunger, around the ball, and down through the holes in the ball retainer, to completely fill the cavity below the ball retainer. Instead of feeding the lifter through the side, some engine manufac-

Fig. 3—Five models of hydraulic valve lifters and their fundamental parts. Reading from top to bottom in the illustration, each lifter consists of the plunger retainer, push-rod seat, plunger, ball check, ball retainer, spring, and body.

turers prefer to feed the lifter through the push rod and into the inside of the plunger via a hole through the push-rod seat. However, the operation of the lifter is the same.

As the lifter is raised by the cam in **position 2**, the oil below the plunger tries to escape past the ball check. This rush of oil around the ball check forces the ball check to seat on the plunger which seals the hole at the bottom of the plunger and the lifter then follows the cam as a relatively solid unit. The travel of the ball check is closely controlled which results in a relative movement between the plunger and the body to seat the ball check.

As the lifter rises on the flank of the cam, and the full load of the valve gear is applied on the lifter, a predetermined and closely held clearance between the plunger and the body permits a controlled amount of oil to escape from below and past the plunger. This condition—the relative movement of the plunger with respect to the body after the ball check is seated—is termed *leakdown.* As the lifter plunger reaches the nose of the cam as shown in **position 3**, the plunger has leaked down a very minute distance relative to the body as compared to its location in **position 2.**

As the lifter reaches the closing ramp in **position 4**, the plunger is lower in relation to the body than in **position 2**, where the ball had just seated. As the lifter continues to ride down the ramp, the ball check opens if the valve gear has remained the same or contracted. The spring under the plunger compensates by taking up the clearance and the cycle is repeated. However, if the valve gear has expanded more than the relative amount of movement of the plunger in the body during leakdown, then the ball check will not unseat until enough cycles have taken place to account for the expansion of the valve gear. Therefore, when the engine structure and valve gear expand and contract with changes in engine temperatures and other differentials, the lifter automatically adjusts its own length to compensate for these changes. When temperature changes require shortening of the lifter length, the engine valve spring forces the plunger down because of the leakdown characteristics, thus constantly correcting for this condition. When lengthening of the lifter length is required, the lifter spring raises the

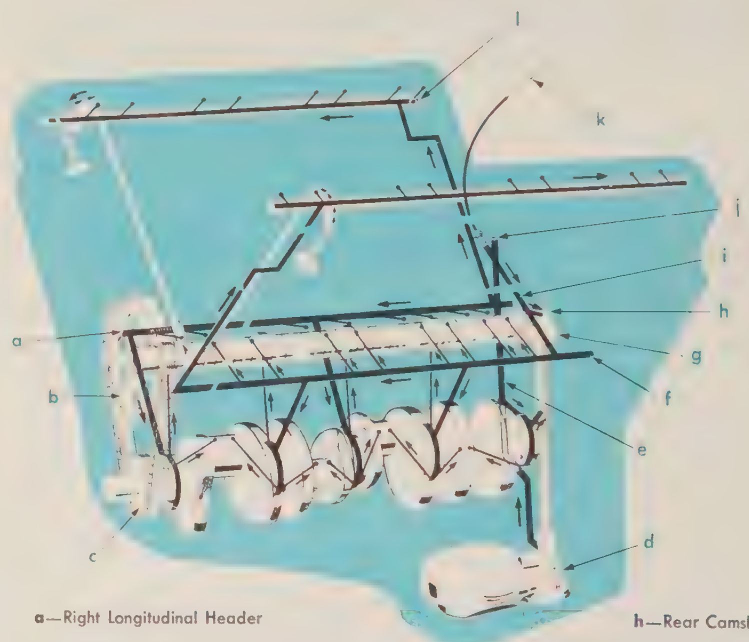


Fig. 4—Phantom view of a typical lubrication system of a V-8 engine illustrating how oil is fed to the hydraulic valve lifters. Oil is forced by the pump through the rear bearing cap to the vertical oil passage, where it flows to the right oil passage, through the connector, to the left oil passage. The oil in both the right and left oil passages flows to the lifters through small drilled holes which connect the passages with the lifter holes.

lunger, causing oil to flow into the pring chamber.

Design Requirements of the Hydraulic Valve Lifter

When an automotive-engine designer esires to use hydraulic valve lifters, ertain facts must first be supplied regarding the engine in which they are to e used. These facts form the basis on hich a hydraulic valve lifter can be esigned.

First, certain external and internal imensions of the engine must be known n order to determine the overall size of ne lifter. The inside diameter *ID* of the ole in which the lifter is to be guided is ne first fact required in order to determine the body and plunger diameters. The method and location of the oil feed o the lifter is next on the list. If the fter is to be fed from the push rod, a ole must be drilled in the push-rod seat o permit entry of the oil. If the oil is to e fed through the body, the dimensions here the oil hole in the block intersects ne lifter hole must be given in order nat the proper registration can be provided for. The diameter or radius of the ush rod that is set in the push-rod seat lso is required as is the amount of space o permit installation and removal of the fter. Finally, it should be determined hether there is to be an undercut on the utside diameter *OD* of the body near ne foot to permit easy removal of the fter body.

The second major item of information o be supplied by the engine designer is ne weight of the valve-gear parts in rder that the proper spring can be esigned for the lifter. The third specication required is the viscosity of the il to be used in order that the proper eakdown specifications may be deternined. The fourth item needed covers ne specifications of the camshaft to be sed. The total lift of the cam is required n order to determine the length of the roove in the body if the lifter is to be d through the body.

If the diameter required on the lifter ot is greater than the diameter of the fter hole in the block, a mushroom-type fter must be used where the OD of the ody at the foot is greater than the OD f the body nearer the top. Although ermitting greater velocities, there are any disadvantages in using the mushroom-type lifter. During engine assembly, nis type either must be placed in position before the camshaft is installed or it requires a specially designed bracket to hold the lifters. Machining and material costs also are greater. Mushroom-type lifters are used primarily on L-head engines. Overhead-valve engines operate with lower velocities at the cam due to the multiplication factor of the rocker-arm ratio which still gives the greater velocities at the valve.

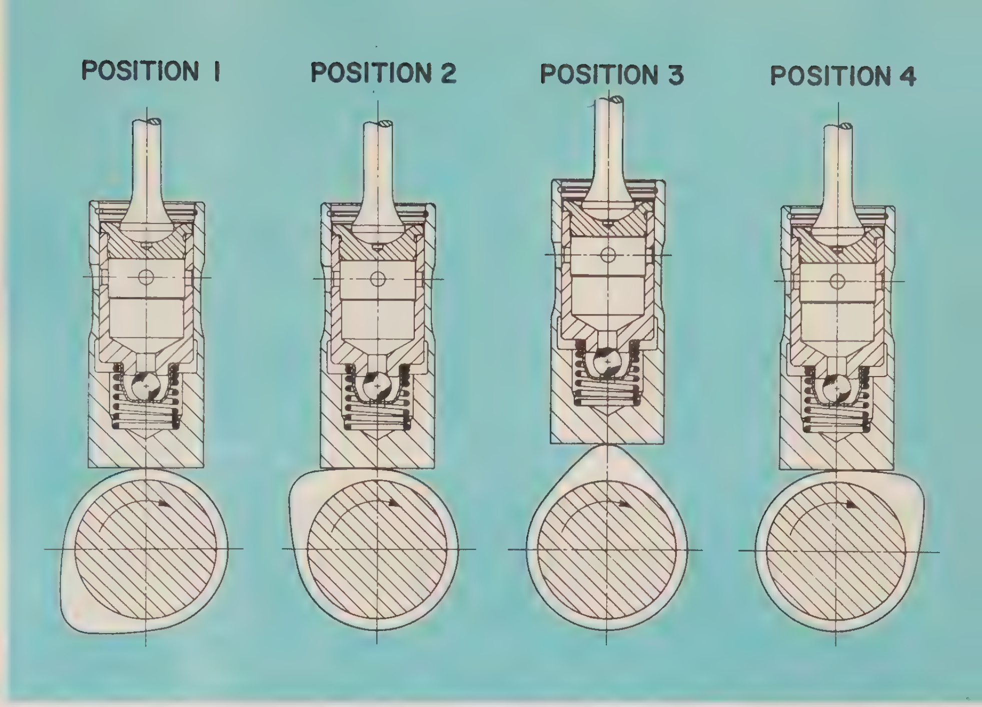


Fig. 5—The four principal cam positions illustrate the operation of the hydraulic valve lifter. **Position 1** shows the lifter on the base circle of the cam. In **position 2**, the lifter is in the process of being raised by the cam, and in **position 3**, the lifter has reached the nose of the cam. In **position 4**, the lifter has reached the closing ramp.

The next thing to be considered is the relationship of the cam to the lifter body (Fig. 6). Both **type 1** with cam and lifter centerlines in line and **type 2** with cam and lifter centerlines offset have the flat cam riding against a flat lifter foot. The flat lifter riding on a flat cam gives the lowest stress. **Type 3** has a lifter with a spherical foot riding against a camshaft with a slight taper. Although it has a higher stress, this third type will withstand a much greater misalignment with little change in stress. The centerline of the cam for **type 3** is offset with respect to the centerline of the lifter.

When using the spherical radius and the tapered cam lobe, it must be remembered that the smaller the spherical radius, the greater is the stress and more misalignment is permitted. Of course, with the large radius, the stress will be lower and the misalignment permitted will have to be held closer. The contact stresses between the lifter body and the camshaft can be calculated by using the conventional Hertz formulae.

The final requirements in regard to camshafts are the type of material from which the camshaft is to be made and the finish that the cams are to have. GM 119M cast iron and S.A.E. 5120 carburized or S.A.E. 52100 steels can be run on alloyed cast-iron camshafts; however, these materials when run on forged-steel camshafts have poor wearing qualities. The only material run to any degree of success on forged steel is the chilled cast-iron lifter body.

Another important consideration is the finish on the lifter foot and the cam face. A decision on whether one or both surfaces are to be coated should be worked out with the metallurgical groups of both the engine manufacturer and the lifter manufacturer, and hundreds of hours of engine testing should be run on the approved materials and surface finishes before being released for production.

Experimental Development Procedures

After obtaining the above information, the project engineer takes his information back to the drafting room, where a lifter is designed which will meet both engineering and production requirements. A layout is then made by the

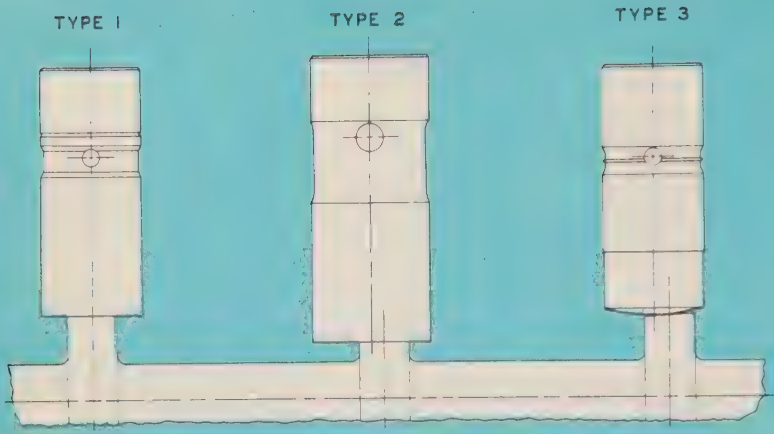


Fig. 6—Diagram illustrating the relationship of the cam to the lifter body. **Types 1 and 2** give the lowest stress but **type 3**, while having a higher stress, withstands a greater misalignment with little change in stress.

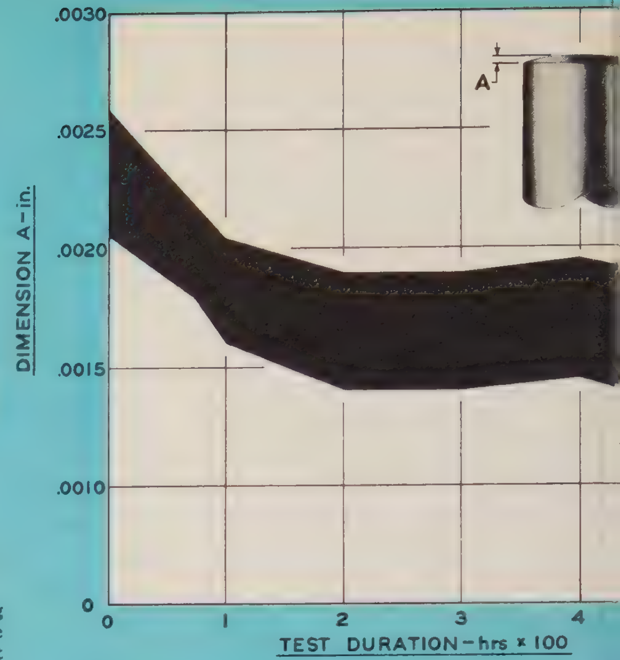


Fig. 7 (Right)—Typical wear curve of a group of experimental lifters undergoing a foot-wear test at specified rpm with no load. On the chart, the width of the band represents values for dimension **A** between which all of the lifters fall at various times throughout the test.

layout draftsman showing the lifter on the base circle and on the nose of the cam to picture both of the extreme lifter positions in the engine.

Once the layout is completed and approved, an assembly drawing is made of the details. These drawings are then submitted to the automotive engineer for his approval.

After approval by the automotive engineer, the prints of the new lifter are sent to the engineering model shop where a small number of samples are made up as an experimental order. The engineering model shop is equipped to manufacture and check any type of hydraulic valve-lifter without the aid of any production machinery, with the exception of the production heat-treat furnaces. In making up experimental lifters, any problems encountered in machining or assembling the parts are brought to the attention of the project engineer in order that these difficulties may be worked out prior to actual production of the lifter.

Check Tests

Aside from the dimensional checks which are made when the lifter parts are being machined, there are three other checks which are always made.

The first is to check the ball seat on the bottom of the plunger. In order to insure a perfect seal, the plunger is placed in a fixture with a ball check located below the plunger as in a lifter assembly. Air is then turned on below the plunger and the ball check is seated.

The second and third checks are made on the *engineering leakdown checker*. The lifter assembly is filled full of a special test oil and placed in the leakdown checker. A known weight is then applied on the lifter. This weight is lowered until the push-rod seat of the lifter is at a given distance from the foot of the lifter. At this distance, the indicator is set on zero, and the time that it takes this combined weight to travel a specified distance from this point determines whether the lifter is acceptable according to present standards of leakdown. If the time span meets the required specifications, the weight is raised from the bottom of the leakdown check and then allowed to drop freely. The distance traveled by the indicator when the weight was dropped freely until the time the ball check seats (when raising the weight, the ball unseats) is referred to as *ball recovery*. This ball recovery must also be within certain preset limits. The ball-recovery check makes certain that the ball travel of the ball check is correct and that the ball check is seating properly.

Dynamometer Tests

A newly designed lifter is first run in a single valve-gear fixture. This fixture accommodates one valve gear of any engine. It is so designed that it can take any valve gear, and this valve gear can be set at any angle. The oil pressure may be fed to the rocker arm—or the lifter hole in the block—or to both places, and the oil pressure can be regulated at both points to whatever pressure is desired. The fixture lends itself very conveniently to the use of instrumentation for observing the action of the valve gear.

After having run a single lifter of the new design, a complete set of these lifters are then placed in a *dummy engine*. This is an engine that does not have any pistons or crankshaft but is run by an electric motor which has a variable speed control. These motored engines are used to give the new lifter design a preliminary approval before trying them in a regular engine.

After the initial testing in the motored engine fixture, a half-set of the experimental lifters are placed in an engine along with a half set of standard lifters. Several engines are used for endurance running, wear testing, oil tests, and general lifter-test work. At periodic times throughout the test, the lifters are removed and rechecked. At the end of the tests, the data are compared and the project engineer can determine the durability of the new lifter.

Determining the Foot-to-Cam Relationship

Whenever the lifter-body or the camshaft specification is revised or there is a dimensional change of the lifter foot or the cam lobe, a foot-wear test is run using one of the test engines. The foot of each lifter is measured by locating the center of the lifter foot and then measuring the difference in the crown height at a specified radius. The overall length of each lifter is also measured. At the start of the test, the cam base-circle diameter and the lift plus the base-circle diameter are recorded for each lobe. The test is run at a specified rpm with no load. At varying intervals of running, the lifters are removed and rechecked on the foot and overall length. At the completion of the test, the camshaft is removed and the base-circle diameter and lift plus the base-circle diameter are again measured. The results obtained with the standard lifters are compared with the experimental lifter results. An example of a wear curve for a group of lifters is shown in Fig. 7. These data along with the lifters and the camshaft are then sent to the metallurgical department for a thorough analysis, and on the basis of the test results and the metallurgical findings, the project engineer determines the desirability of using the new foot-to-cam relationship. If the new relationship is acceptable, further endurance and foot-wear tests are run again on a dynamometer, only at higher speeds and with the engine operating under full load.

Oil-Pressure Tests

Another important dynamometer test is known as the *pump-up* and *pump-down* test—or the maximum speed the engine will run at varying oil pressures. The engine is set at a certain speed and full load is applied to the engine. Oil is supplied to the lifters by means of an external pump in order that the oil pressure may be varied. The oil pressure is slowly increased until the engine begins to lose load. This is termed *pump up* and is caused by lifters holding the valve open due to the fact that the oil pressure is too great to permit proper seating of the valve. Oil pressure is then decreased until the engine becomes noisy, at which point the oil pressure is increased until the engine becomes quiet. This is the *pump-down* pressure. The dynamometer operator then increases the speed of the engine to the next speed to be checked and repeats the same cycle.

From these results, a curve can be drawn which is compared to a similar curve obtained for standard lifters. Often low-load engine valve springs are used to purposely cause the engine to malfunction at lower rpm's. Final designs are tested at full-production valve-spring loads. Other factors such as valve-spring loads, cam contour, lash of the timing gears, lifter leakdown, and valve-gear weight can and do affect engine speed, and sometimes, in the design of a new lifter, some of these need to be revised to give added speed.

In cases where the oil pressure is too high, resulting in pump up at low speeds, the designer often resorts to restrictive feeding of the valve lifter. This can only be done when feeding the lifter through the side of the body. The engine is so designed that the oil feed from the engine does not register with the lifter-body-feed groove when the lifter is on the base circle but only when the lifter is near the top of the nose of the cam. Therefore, when the lifter does register with the engine oil feed due to the high loading on the valve lifter, the tendency for pump up is lessened and in some cases there is a considerable gain in rpm.

Verification Tests

The final test of the lifter is made by placing several of the production models in test cars. These cars, which are run at all speeds and varying mileages, give the project engineer a good overall test of the lifter. While this final test is going on, the project engineer sees that the automotive group or groups interested in the lifter are supplied with several hundred samples on which they run tests similar to those described above. After thorough testing and evaluation, and when everyone concerned has finally approved the lifter for production, a release is received from the engine manufacturer, and all experimental numbers on the detail and assembly prints are replaced by the given production numbers.

Production Stage

When the lifters are put into production the bodies, plungers, and push-rod seats are turned out on a screw machine while the ball retainers are stamped out; the springs, plunger retainers, and balls are purchased. Centerless grinders grind the plungers and bodies after heat treat. After being ground on the OD and the foot, the bodies are honed to give them a super finish on the ID of the body to match with the ground finish on the OD.

After completion of the machining operations, the plunger OD and the body ID are measured and put into numbered racks. Operators then take the matching plunger and body and assemble them with the other remaining parts. The completely assembled lifter passes through a specially designed machine which checks the leakdown and the ball recovery of each lifter. The same high standards must be met in production as were initially designed into the experimental lifters.

Finally, the finished lifters are packaged and shipped to the automotive-engine manufacturer for use in a new engine.

Once a manufacturer has been supplied with lifters, the project engineer's work does not stop. He continually checks the production assemblies and field reports, working with the engine manufacturer for added improvements and better quality at reduced cost.

Conclusion

Hydraulic valve lifters provide automatic compensation for the expansion and contraction of valve-gear and engine structures caused by engine temperature changes and differentials as may exist in automobile, truck, tank, or Diesel engines. Any engine design incorporating a valve which is opened by a cam is a potential user of the hydraulic valve lifter. To achieve the required exact specifications and durability, this device is subjected to a continual testing program involving dimensional machining, ball-seat, leakdown, and ball-recovery checks before a production design can be considered. Even then, investigation does not cease but further verification tests are conducted on the finished product.

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Solving the Design and Development Problems of Automobile Door Locks

By JAMES D. LESLIE
Fisher
Body
Division

A safe, reliable mechanism operates within a restricted space

The design of a new automobile door lock consists mainly of fitting a mechanism, required to meet a variety of operating specifications, into a restricted space determined by the automobile-body styling. The choice of latching means and actuating means, or handles, also is dictated by styling requirements. Throughout the design and testing stages, the most important considerations are safety, reliability, operating ease, and reasonable cost.

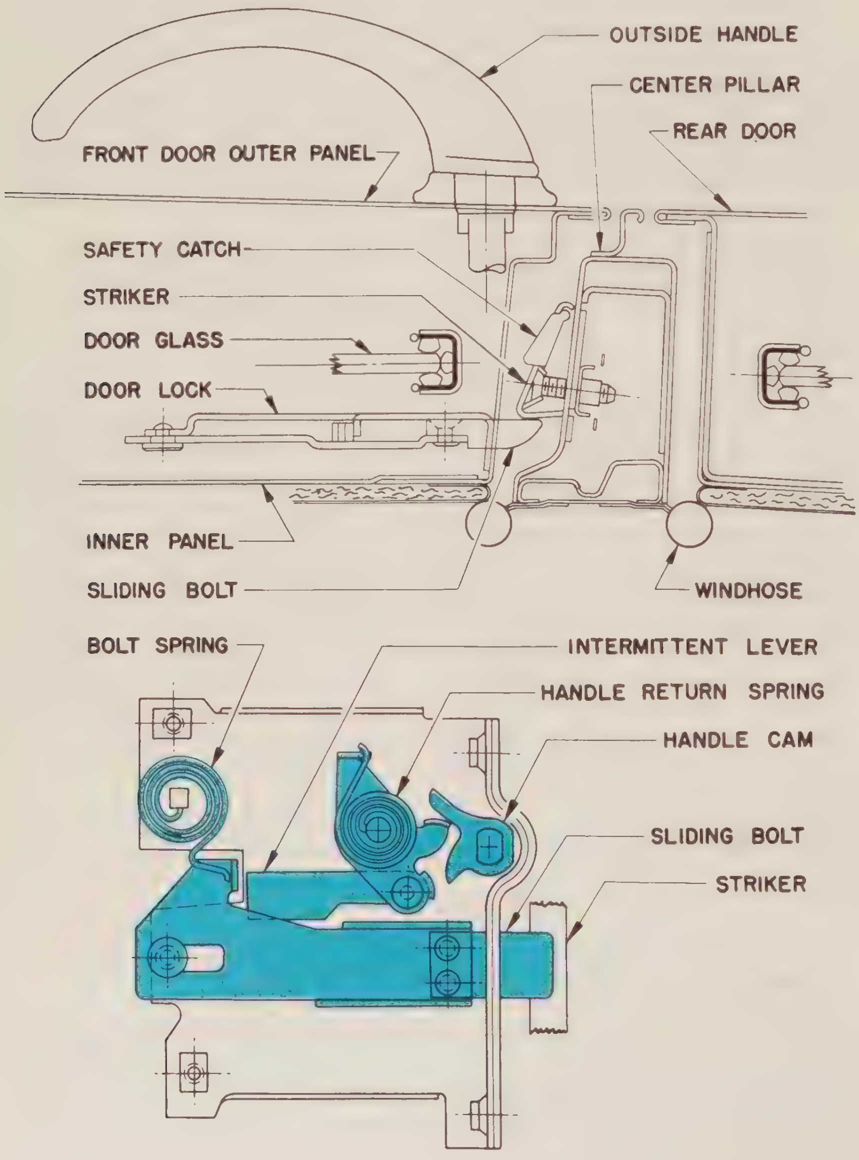


Fig. 1—Sliding-bolt-type door lock used in older car models. Latching was achieved by a horizontally sliding bolt which was forced out of the door by a bolt spring into engagement with the *striker* or keeper.

UNTIL about 20 years ago, virtually al cars employed the *sliding-bolt-typ* door lock. In its simplest form, this lock was similar to a *cabinet* or house lock in that latching was achieved by the use of a horizontally sliding bolt which wa forced out of the door by a bolt spring into engagement with the *striker*, or keeper, on the door jamb (Fig. 1). It differed from a house door lock, however, in that vibration between the door and body opening tended to force the bolt back to the unlatched position. Thi made it necessary to use a heavy bo spring to insure the safety of the latch The effort required to retract the bo against the heavy bolt spring, in addition to that necessary to overcome the fri tion of the bolt on the striker, compelle the use of a turn handle.

The sliding-bolt-type lock generally met the requirements of the body styling of the time. The body-side contour turned inward as shown in Fig. 2. Thi caused water to run out of the door *rabbets** so that only the *windhose* wa required to seal a body opening. The door-contour turnunder also provided adequate clearance for using a turn handle. Body-styling advances, however gradually changed the body-side contours so that they sloped outward toward the bottom (Fig. 2). This change, coupled with the introduction of *CV*'s which reduced the air pressure inside the car, necessitated the addition of a rubber weather strip to the door rabbets in order to sea water out of the body. The additiona force required to compress the weather strip increased the seal force exerted against the lock bolt. The physical effor required to turn the handle and retrac

*For glossary of some body-engineering terms, se p. 25.

e bolt was increased because of the crease in the frictional force between e bolt and striker. The door-surface ntour just below the outside handle, rthermore, often interfered with rotan of the handle. This required a reducn in the angle of rotation of the ndle and, as a consequence, a further crease in handle-turning effort. These anges made doors not only more difficult to open but also more difficult to ose.

The opening effort was reduced by anging from the sliding-bolt-type of tch to *rotating* or *rolling-types* which were tched or detented internally. Where dy styling permitted, some of these cks continued to use the rotating ndle, but the operating effort was eatly reduced because internal latching ermitted lower spring forces and duced movement of the latching members. This also made it practical to adopt e push-button method of actuation.

Changes in body styling will continue force redesign of door locks and ndles. The trends in recent years of nging the rear doors of sedans on the nter pillar has reduced the space available for the front-door lock mechanism order to provide room for the rearor hinges. Reduction in the height of e sedan rear-door lock pillar above the *g leg* has made it necessary to incorrate the dovetailing device, which prents vertical vibration of the door, into e latch mechanism. Continued mands for reduction in the width of e sedan center pillar to eliminate the ind spot at the side windows also have duced to a minimum the space available for the lock mechanism between the ont and rear-door *window channels*. As rs become lower, and the windowening line moves downward, it bemes desirable to mount the outside ndle on the *reveal molding*. All of these ling trends demand continual revision door-lock designs.

Design Requirements

fety

Although advances in body styling ay dictate the necessity of a new or vised lock, the paramount design conleration at all times is the *safety* of the cupants. No concessions are made to ling or cost where the factor of safety involved. The absolute requirement at the lock hold the door securely osed during all driving conditions is given close attention during all stages of design and testing.

The latch must be strong enough to withstand the weight of the occupants being thrown against the door. It must be provided with a secondary or safety catch to prevent the door from opening if just barely latched. Inside handles must be located and designed to turn in such a direction to enable them to be easily grasped by the occupants and yet not be subject to accidental turning resulting from the occupants' movements. The latch must be free from any tendency to jam if the car body is distorted by collision. Rear-door locks of sedan bodies by Fisher are provided with an additional mechanism that causes the inside handle to *free wheel* or move without opening the door when the locking button on the *garnish molding* is depressed. As a convenience for owners who seldom carry children as rear-seat passengers, the dual operation of pulling up the locking button and then turning the handle can be eliminated through an adjustment of the lock mechanism by a dealer. The lock then performs like the one in the front door which is both unlocked and unlatched by turning the inside handle. This is called the rear-door *selective free-wheeling* feature.

Operating Convenience

For convenience of operation, the lock should open with a minimum of door-handle or push-button effort. It must absorb only a small fraction of the effort required to close the door. The control must be such that it is easily locked and unlocked. In locks on bodies by Fisher, a mechanism is incorporated which permits the latch to be locked when the door is closed—without using the key. This is accomplished by depressing the garnish-molding button and pushing in the outside-handle push button and holding it in as the door is being closed. This is called the *keyless-locking* feature. Failure to push in and hold the outside button while closing the door will cause the mechanism to be un-dogged or moved to the unlocked position.

Resistance to Elements

The lock mechanism must be capable of operating throughout the life of the car with a minimum of cleaning, lubrication, adjustment, or any other type of servicing. This makes undesirable the use of delicate mechanisms with small clearances which might be rendered inoperative by dust or frozen condensation.

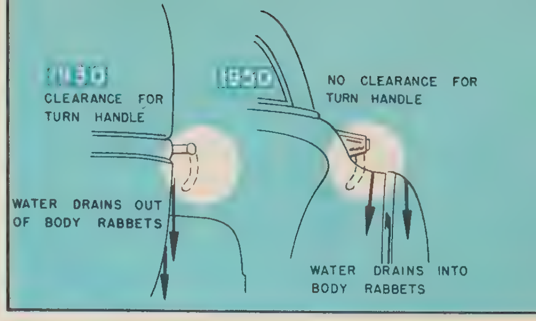


Fig. 2—Changes in body contours over a 20-year period gradually affected the design of locks and handles. (Left) The door contour turnunder of the 1930 car model allowed adequate clearance for using a turn handle. (Right) Advances in body styling as shown in the 1950 model required a reduction in the angle of rotation of the handle, thus increasing handle-turning effort.

Ease of Manufacture

The parts of the lock must be designed for fabrication by high-output, low-cost methods such as stamping from sheet metal in progressive dies, zinc-die casting, screw machining, and projection welding. Operations such as drilling, sawing, spotfacing, and hand welding are costly and undesirable.

Choice of Latch Actuation

Outside Door Handles

The type of outside door handle to be used is one of the first decisions that must be made before a door lock is designed. The common types of handles are shown in Fig. 3. The following are their individual characteristics:

- *Turn handle* provides a large amount of force for locks that are difficult to unlatch, but it is somewhat awkward to use. It requires a counterbalance spring to hold the handle in a horizontal position.
- *Restricted turn handle* may be used where the angle of turn is reduced by the door shape, but the smaller turn area increases the force required to turn.
- *Pull handle* makes use of a natural motion for opening the door, but the door tends to jump open when the latch clears. Control of the door position when opened is more difficult because the handle is movable.
- *Trigger handle* provides styling novelty but is often awkward to operate and susceptible to freezing.

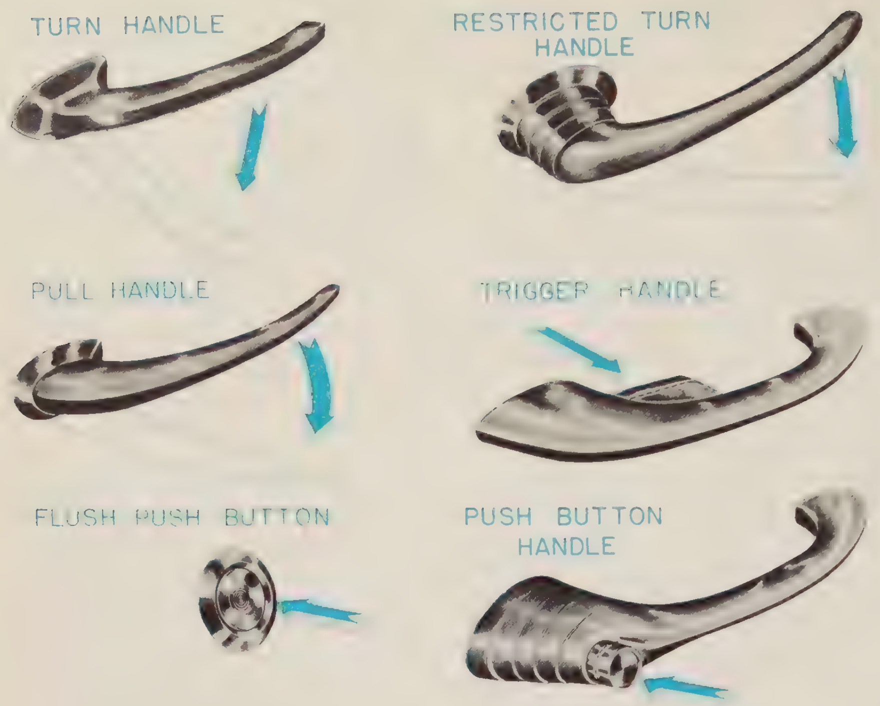


Fig. 3—Some common types of outside door handles. Of the six designs shown, the push-button handle is the most convenient to operate and gives full control of the door. Its main limitation is that it increases the bulk of the handle and supplies only a small operating force to the latch.

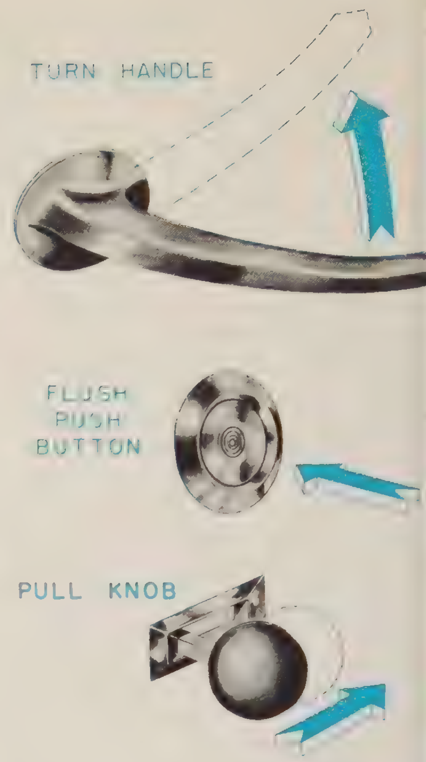


Fig. 4—Common types of inside door handle The turn handle permits easy operation and goo control of the door swing but must be position to avoid accidental opening. The push-button type is often awkward to operate and difficult t place in a safe location. The pull knob is con venient to operate but control of the door swi is difficult.

- *Flush push button* provides a door surface free from projections but requires an additional mechanism to force the door open far enough to permit the edge to be grasped. It is usually susceptible to freezing and provides little force to operate the latch.

- *Door-handle push button* is the most convenient to operate and gives full control of the door, but increases the bulk of the handle and supplies only a small operating force to the latch.

Inside Door Handles

The type of inside door handle to be used is important in the design of the lock. It is generally one of the types shown in Fig. 4. These are:

- *Turn handle* is easy to operate and provides good control of door swing but must be positioned to avoid accidental opening by occupants.

- *Push button* eliminates a projection inside of the door, but is often awkward to operate and difficult to position in a safe location. It furnishes only a small operating force to the lock and does not provide control of the door swing.

- *Pull knob* is convenient to operate and furnishes a large operating force to the lock, but control of the door swing is somewhat difficult.

Choice of Latching Mechanism

Space Layout

After the types of handles have been decided upon, a layout drawing is made to show the *swing line*, *shut bevel*, outside-handle position, and the space available for the door lock in the door and body pillar. This is a composite layout which includes all of the doors for all of the body styles on which the lock will be used. This layout provides the boundaries of the space that the lock parts may be allowed to occupy in the body. From this space must be subtracted certain clearances that have, from past experience, been found necessary to insure reliable operation. The space which a typical lock installation on bodies by Fisher occupies is shown in Fig. 5.

Into the space so determined must be fitted the latching device, operating mechanism, and controls. A number of latching means commonly used are shown in Fig. 6. The fork bolt, cam bolt, gear and rack, and roller and inclined slot are internally detented and may be used with any type of handle.

The latching device, the mechanism required to operate the lock from th door handles, key cylinder, and garnish molding buttons are then designed t operate within the space available. Th layout is drawn full-size so that propor tions may be more easily visualized. Th is probably the most important and diff cult step in the design of the lock. I involves many different conditions tha must be satisfied and requires the selec tion of many compromises from amon the design requirements. Since no com promise can be made to safety, it i established policy to over-design fro the strength standpoint so as to make th lock as rugged and durable as possible

Force Analysis

When the general design of the loc has been established, a force analysis i made to determine the approximat forces acting on the mechanism, th operating forces, and the effectiveness o the dovetail geometry. In a push-button operated latch, the push-button forc

quired to unlatch must be carefully nalyzed. The spring forces acting on e push button must be high enough to revent *door bounce* under hard slams as ell as provide a positive "feel" when e door is unlatched. On bodies by isher, the radius of the detent surfaces located slightly off the pivot-center of e detent so that a component of the al force acts so as to reduce the push-utton force. The push-button effort sulting from forces acting on the detent ver of the lock can be determined, for xample, by considering the lever as a ee body as shown in Fig. 7 where:

S = the seal force of the door. It has a nominal value of 100 lb.

r_1 = the pitch radius of the latch gear. In the calculations a value of 0.53 in. is used.

r_2 = the radius of the latching cam. This cam is attached to the gear shaft. A value of 0.69 in. is used in the calculations.

r_d = the radius of the detent. Although the lever pivots about point **o**, the shape of the detenting surfaces is defined by a radius from point **c**. A radius of 1.85 in. is used in the example.

d = distance between points **o** and **c**. This is the off-center distance of the detent radius.

F_s = detent spring force (lb).

T = detent-spring torque (lb-in.). A value of 7 lb-in. is used in the calculations. $T = F_s \times l$.

F = friction force acting on detent surface (lb).

D = normal force on detent surface (lb).

P = push-button force required to move detent (lb). The actual button force would be increased by the force required to move the mechanism between the push button and detent lever against the spring force or by about 3 lb. Since the multiplier lever has a ratio of about 2:1, this force is shown as having a reaction of $2P$ on the detent lever.

a = length of lever arm on which force from push button acts (in.). A value of 1.04 in. is used in the calculations.

μ = coefficient of friction at the detenting surfaces.

n equating the moments at point **o**, the enter of the detent rivet, it can be seen at the friction at the detenting surfaces nd the spring force is opposed by the f-center load on the detent cam and the

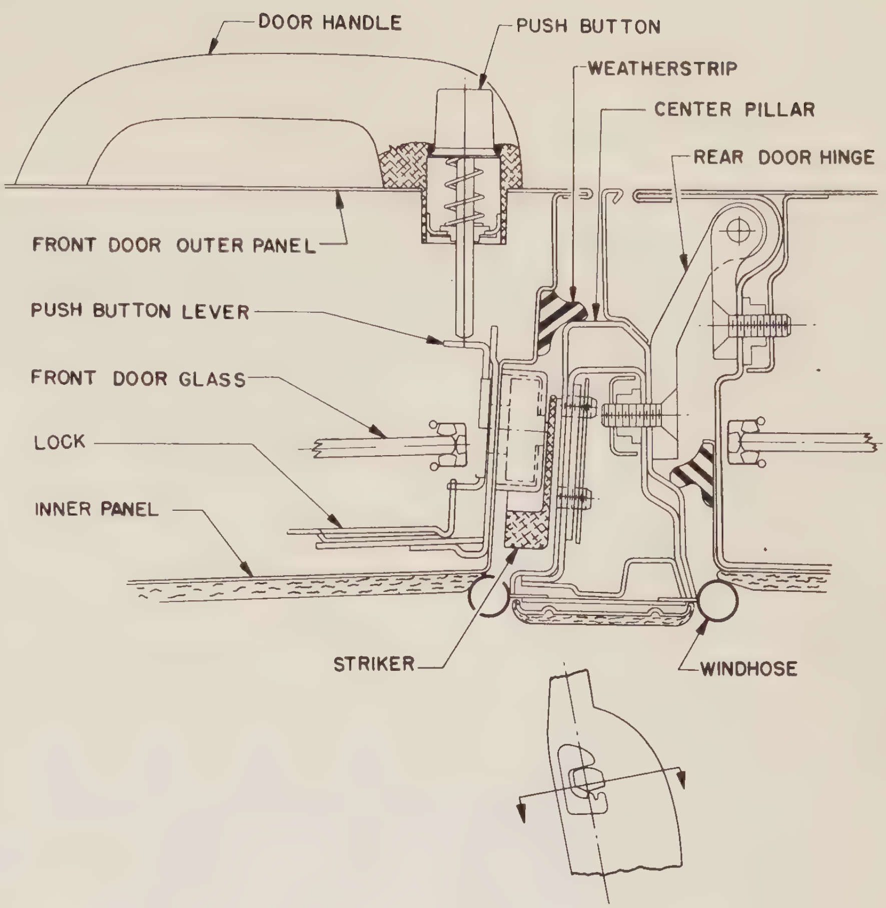


Fig. 5—Layout of a typical lock installation on bodies by Fisher showing the boundaries of the area that the lock parts can occupy in the body.

force from the push button so that, neglecting friction at the detent rivet:

$$\Sigma M_o = -Fr_d - T + Dd + 2Pa = 0$$

or

$$P = \frac{Fr_d + T - Dd}{2\,a}$$

since

$$D = \frac{Sr_1}{r_2}$$

and

$$F = \mu D = \frac{Sr_1}{r_2}\mu$$

then

$$P = \frac{S\frac{r_1}{r_2}r_d\,\mu + T - S\frac{r_1}{r_2}d}{2a} = \frac{Sr_1}{2\,ar_2}(r_d\,\mu - d) + \frac{T}{2a}.$$

Substituting numerical values:

$$P = 0.37\,S\,(1.85\,\mu - d) + 3.4.$$

Examination of this equation reveals that, with the proper selection of the off-center distance d for a given coefficient of friction μ, the calculated push-button-force variation for different seal forces S can be made to increase, decrease, or remain constant.

Using a coefficient of friction $\mu = 0.15$, which measurements have shown to be a nominal value, and an off-center distance, $d = 0.047$, which was initially selected for this particular latch, then:

$$P = 0.37S\,(1.85 \times 0.15 - 0.047) + 3.4$$

$$P = 0.085S + 3.4$$

and, when $S = 100$ lb:

$$P = 0.085 \times 100 + 3.4 = 11.9 \text{ lb}$$

and, when $S = 200$ lb:

$$P = 20.5 \text{ lb}.$$

This indicates that the push-button effort would theoretically increase in proportion to the door-seal force but remain conveniently operable within the seal-force range.

If other important factors were ignored, it would be possible to have a latch, by proper choice of an off-center distance, whose push-button force was independent of the door-seal force. In such a case, continuing to use $\mu = 0.15$,

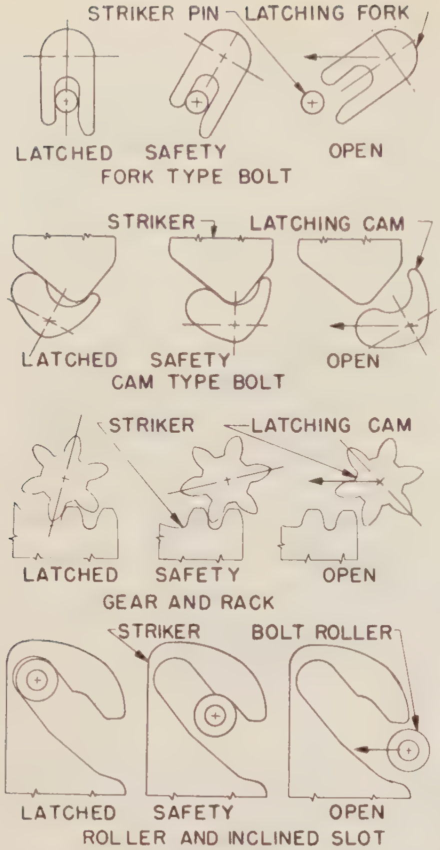


Fig. 6—Some common latching means. These are all internally detented and may be used with any type of handle.

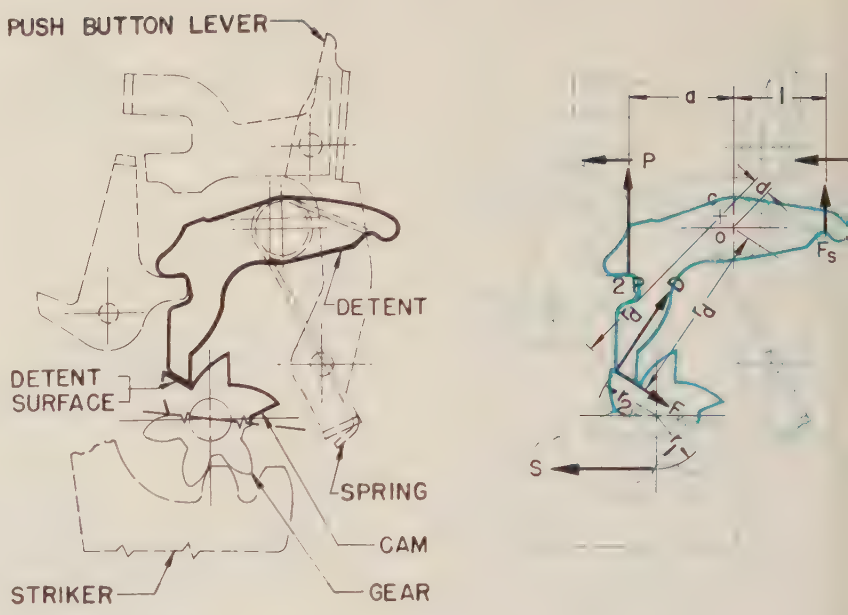


Fig. 7—(Left) Diagram identifying the main latch detent-force components used in force analysis. Th force analysis determines the push-button effort resulting from forces acting on the detent lever of the loc considering the lever as a free body. (Right) Latch detent-force diagram where S is the seal force of t door; r_1 is the pitch radius of the latch gear; r_2 is the radius of the latching cam; r_d is the radius of t detent; d is the distance between points **o** and **c**; F_s is the detent spring force (lb); F is the friction for acting on the detent surface; D is the normal force on the detent surface (lb); P is the push-button for required to move the detent (lb); a is the length of the lever arm on which the force from the push butt acts (in.); μ (not shown) is the coefficient of friction at the detenting surfaces.

and equating the quantity $1.85\mu - d$ to zero:

$$d = 1.85\mu = 1.85 \times 0.15 = 0.278 \text{ in.}$$

and

$$P = 0.37S(1.85 \times 0.15 - 0.278) + 3.4 = 3.4 \text{ lb.}$$

It can be readily calculated, however, that a decrease in the coefficient of friction μ below 0.10 would result in a negative push-button force P which means that the latch would not hold statically. An off-center distance as high as 0.278 in. would, then, be unsafe.

Continued vibration over a period of time at normal seal forces tends to cause creep, or a gradual movement of the detent to the unlatched position, so that the coefficient of friction can be assumed to decrease to zero under vibration in the car, and the limiting value of the off-center distance would be one which would give a zero value for push-button force when $\mu = 0$ as follows:

$$P = 0.37S\,(1.85\mu - d) + 3.4$$

$$O = 0.37S\,(O - d) + 3.4$$

or

$$0.37Sd = 3.4$$

and

$$d = \frac{3.4}{0.37S} = \frac{9.2}{S} = 0.092 \text{ in. for 100 lb seal force.}$$

This value (0.092 in.) would then be the theoretical upper limit for the off-center distance for the conditions stated.

The values determined from the above equations are affected by many other variables such as clearances of parts, manufacturing tolerances, variations in surface finishes and lubrication, and wear of the parts so that they serve only as initial design figures that may be radically altered by the time the design and testing are complete.

When the force analysis indicates that the design of the lock is basically sound, a full-size working model is made of transparent plastic to help visualization of the parts.

Production Design

The discussion of the lock design up to this point has been concerned mainly with obtaining the best possible mechanism to meet styling and body requirements. Once this has reached an acceptable conclusion, the production design is begun. An experimental layout drawing is made in which the lock details are re-designed to permit them to be ma using the methods and the equipme available in the manufacturing pla which will produce the parts. T designer works closely with the produ tion and tool engineers to determine t most economical method of making t various parts, the tolerances that can held, and the location of tooling ho used to index the parts in the dies. T production tolerances shown on the e perimental drawings for the various pa are then incorporated into the most e treme combinations in high-low tole ance layouts. These layouts are made determine whether manufacturing vari tions will affect the safety and operati of the lock. They also establish the ran of operating clearances permitted in t inspection of the lock assemblies. T production drawings of the lock that w be used to design tools, and manufactu and inspect the lock and its parts are th made from the experimental and hig low tolerance layouts.

Testing Procedures

Laboratory Tests

Hand-made samples of the lock a striker are made as soon as the expe

nental drawings are completed. Some of hese are tested for operating charac-eristics, such as push-button effort and closing force, in a laboratory lock-testing ixture which can be set up to duplicate he shut bevels and swing lines of all of he different door styles for which the ock is designed. Wear of the operating parts is observed by testing some of the amples in laboratory slam fixtures which automatically open and close the door section of the fixture until failure occurs. Operation of the lock at low tempera-tures is observed by installing it in a car and subjecting the mechanism to succes-sive cycles of washing and freezing in a cold room. The door-lock mechanism, cylinder lock, and outside door handles are subject to 24 hours of salt spray.

Road Tests

The functions of the lock mechanism are so complex, the safety requirements are so rigid, and the forces to which the lock are subjected in service are so varied that laboratory tests are supplemented by extensive road and slam tests.

The locks are installed in cars with bodies altered to accept the new design, and then are subjected to a comprehen-sive test procedure which has been devel-oped over a period of years to determine the durability of a lock. These tests are conducted at the General Motors Prov-ing Ground at Milford, Michigan, and include 50,000 normal-service door slams, and driving over 2,000 miles of the Belgian Block road, 200 miles of rough track, and 150 miles of gravel road, chatter bumps, and timber road.

The door slams are administered by a portable slamming machine. The prod-uct of the distance the door is opened and the average force exerted over that distance in closing the door is a measure of the slam energy. For a normal service door slam, this is 10 ft-lb or high enough to insure closing almost any door. The inside-handle remote-control linkage is checked for satisfactory operation through 25,000 slams in which the latch is actu-ated by the inside handle. A latch design also is required to withstand an extreme service test of 50,000 slams of 25 ft-lb. Such service might be encountered in taxicab or delivery use.

Periodic safety checks of the latch-hold-ing strength are made during the dura-bility driving on the roads. This is done by setting the lock mechanism so that the detent is only one-third engaged, and then driving the car on the roads with outward loads up to 400 lb applied to the doors with an air cylinder. The mechanism is required to hold safely or move to the fully latched position.

During the course of development, as many as 100 locks are subjected to this testing procedure. This often results in a considerable change in the design. The tests are made of nominal, or random tolerance, locks at various stages of devel-opment up to and including production assemblies. Locks are also made to the most extreme limits permitted by the production tolerances as determined by special high-low layouts. In addition, locks which have been entirely degreased are tested to determine whether the mechanism will operate properly and hold the door safely closed even though operation of the lock may require more effort.

Conclusion

The development of each new auto-mobile door lock tailored to the speci-fications of new automobile models is essentially an empirical design field. The usual technical complications involved in any new design program are intensi-fied by the demands of constantly chang-ing styles and body contours.

Devising a new car door lock embodies a series of design compromises. The latching means must be strong enough to hold the door shut even though pas-sengers might be thrown against the door, yet it must be free from any ten-dency to jam. Inside handles must be located and designed to be easily grasped yet not be subject to accidental turning. In addition to considerations of operat-ing ease and safety, locks also must be designed to offer high resistance to the elements and permit ease of manufacture.

Glossary

For paper beginning on page 20: "Solving the Design and Development Problems of Automobile Door Locks."

Body opening is an opening in the body surface to fit the outer edge of the door.

CV is the door-ventilator assem-bly. The term is derived from *con-trolled ventilation.*

Dog leg is that portion of body pillar formed by the housing over the rear wheel projecting into the door opening.

Door bounce is a condition which occurs under extremely hard slam where the inertia of the outside push button causes it to unlatch the lock when the door stops on the weather-strip. This causes the door to bounce back to safety position.

Garnish molding is the painted or chrome-plated molding around the periphery of the window opening on the inside of the door.

Rabbet is a step in the door-lock pillar face which receives a mating step in the body pillar face to con-ceal the clearance between the door and body opening.

Reveal molding is the chrome-plated molding around the peri-phery of the window opening.

Seal force is the total force re-quired to hold the door in the closed position. It is the sum of the forces exerted by the weatherstrip, wind-hose, and door bumpers.

Shut bevel is the term used to denote the angle between the lock pillar face and the inner panel of the door. Shut bevel is required when the position of the hinge centerline would cause the inner corner of the door face to strike the body pillar face during the closing of the door.

Swing line of the door is the angle to the horizontal at which the door rises as it is opened.

Windhose is a welt attached to the inside trim around the body opening —generally fabric-covered rubber tube or cord. Also called *windlace.*

Window channel is a U-shaped channel used to grip and guide the door windows. It generally uses hair-felt in contact with the glass to mini-mize friction and is often called *glass run channel.*

Chevrolet Engineering and Product Development

Foreword

The training of engineers by industry is a never-ending task. Every year there are lost, through retirement, the invaluable services of men who have built and molded their companies. They must be replaced by men of the same vision and capacity.

Another factor which adds to the task is the expansion of engineering which has taken place in our era. This is not a phenomenon, occurring once in a decade, but a verified trend which will continue indefinitely into the future. Never before has there been such a need for engineers—engineers of the highest caliber.

In the case of Chevrolet Motor Division, two types of engineer are utilized; the specialist and the staff engineer. There has been much pressure towards specialization due to the enormous growth of our industry and the complexity of its products. Thus, we have engineers who have spent their lifetime on transmissions and gearing, others on power plants, and still others who have brought the processing and shaping of metals from the rather crude stage of trial and error down to a point where they can predict the requirements of a design by the use of scientific methods. But, while a natural development, the tendency toward specialization produces a man with intensive knowledge in a limited field and one who may become restricted in his view of the overall picture.

These men are not especially suited to exercise broad general direction over a program and to give it unity and purpose. So, while acknowledging the irreplaceable contributions of the specialist and encouraging his efforts, we must, at the same time, train men who can give direction to the many-sided engineering effort.

The easiest solution, and one that has been often advocated, is to encourage men to broaden their outlook by taking a liberal arts degree before specializing. We must recognize that few men can afford to be unproductive for that length of time. The more realistic solution is to give men in industry the opportunity to develop their latent potentialities.

Observation and experience suggest that there are three fundamentals which must be considered in supplementing the engineer's formal training: (a) rotational experience, (b) technical broadening, and (c) managerial training.

It has been noted that nearly every outstanding engineer has had some rotational experience. Unfortunately, it was sometimes gained in a haphazard or accidental manner and frequently occurred late in the man's career. Therefore, it seems advisable to provide for systematic rotational experience while the engineer is still a young man. There is a strong feeling that rotational experience is of less value after ten years in the profession.

Another provision should seek to offset the effects of specialization by encouraging technical broadening. Today's engineers have shown their desire to escape the narrow confines of overspecialization by their interest in furthering their education and by their alert participation in the activities of the technical societies. Industry might take this one step further by arranging lectures by the older engineers for the benefit of the younger members of the organization. This is especially desirable because it would serve to perpetuate the irreplaceable knowledge and experience of the older "founders."

Finally, there is the need for managerial training. Engineers are promoted principally because of their technical ability. With the promotion, they are suddenly faced with the job of organizing programs and dealing with people. They need to be equipped with skills which will enable them to fulfill these managerial duties.

There you have the ways in which industry may assume the responsibility it shares with the engineering colleges for the education of the engineer. The men who come to us are excellently trained. It remains for the industry to broaden them and equip them to be the future leaders of industry and of their profession.

E. N. Cole

EDWARD N. COLE
Chief Engineer
Chevrolet Motor Division

WIDESPREAD decentralization, which is typified by Chevrolet's 28 plants dispersed through 20 widely separated cities, makes it difficult for the mind to grasp the meaning and interaction of all the many activities of a large organization. Even one dimension of the organization, its size, makes it difficult to understand. If all of the Chevrolet activities were enclosed in one building, it would be about a mile square and humming with the activity of over 90,000 Chevrolet employes. Adding the other dimensions presents the further complication of having to span the vast distances between the Los Angeles and Baltimore plants or the Janesville, Wisconsin, and the Atlanta plants.

One of the best ways to attack this difficult subject is by the technique of sampling. Once familiar with some of the locations which are representative, the mind can magnify what it has seen int a fairly accurate concept of the whole.

This is the way Chevrolet introduce the organization to its graduate enginee and it seems the most appropriate wa to introduce it to anyone who is unfa miliar with this Division's organizatio and work. Therefore, sit in at a confe ence held a few days ago in the Enginee ing Department at the Chevrolet Centr Office in Detroit. Some of the men a

Prepared by

Engineering Department,

Chevrolet Motor Division

Young graduates sample the engineering activities of an auto maker

Conferring in the office of Mr. Collins, the executive assistant chief engineer, are, from left to right, Bill Konopacke, Charles Oliver, P. A. Collins, and Dave Martens.

nding were finishing their *familiariza-n period* and had been called into the fice of the Chevrolet executive assistant ief engineer, P. A. Collins, to see what ey had gained through their experience.

The first man Mr. Collins talked with as David Martens, a graduate of Iowa ate College.

COLLINS: How long have you been this program, Dave?

MARTENS: Well, about two years. other words, I have almost finished e program.

COLLINS: In the time you have been ith us, have you developed an interest any particular branch of our opera-on?

MARTENS: Primarily, I'm interested engine-design work. Not only from a eoretical but from a practical stand-oint. Although engines are my first terest, I am also interested in the hole car.

COLLINS: What was your first work signment here at Chevrolet?

MARTENS: I spent the first three onths at the Central Office here in etroit. Approximately two months were ent in detailing; that is, taking the rts from the layout drawing, drawing em separately, and adding dimensions. he other month I spent in layout work hich is primarily design, checking, and forth. During this time I certainly came acquainted with quite a few the parts of the car—and I learned w to draw. Although my previous job d been about 50 per cent drawing, my chnique wasn't too good. I learned ite a bit about drawing—and I thought knew.

COLLINS: What was your next as-gnment?

MARTENS: I went to the Chevrolet xperimental Laboratory and worked for Mr. Richard Barnard (superintendent of Laboratory Tests). I stepped right into it there. They handed me a tough job right off the bat, checking some frame sections. I spent a month on the floor out there doing physical frame test work, a month writing technical reports, and a month in the engine laboratory running economy tests, power checks, and so forth.

After that I went to the Proving Ground at Milford, Michigan, where we spent most of the time running special tests. Most of the tests were on the Chevrolet but there were some tests run on competitive cars. In addition, we did checks for other information on GM cars. The Experimental Laboratory tests parts or some of the completed assemblies, whereas the Proving Ground tests the whole car. Maybe you're interested in only one part in the car but it is given an actual road test.

COLLINS: Let me interrupt you here Dave, to bring one of the other fellows into this. How about you Charles (Charles Oliver, a graduate of Wayne University in Detroit), what is your special interest?

OLIVER: My special interest is in body design.

COLLINS: Did you start in the drafting room, too?

OLIVER: Yes, Dave and I were together for the first nine months. There is little I can add to what he has already said about the drafting room and the Proving Ground. However, my first month at the Experimental Laboratory was spent in physical frame and body testing, which is my primary interest. We did considerable work on aspects of physical frame and body testing: model bodies alone, body and frame combinations, and frames alone—even component parts. We tested them torsion-wise and beaming-wise on the surface plate to find their deflection rates and such.

COLLINS: Bill (Bill Konopacke, a graduate of Michigan College of Mining and Technology), have you anything to add?

KONOPACKE: My first assignment was at the Proving Ground. There we were assigned to work with different men, to observe and record data that were taken during special tests we ran. We learned various tests such as checking the accuracy of the speedometer and the odometer, brake deceleration, performance, and economy. And there were different tests on the Powerglide transmission which is my particular interest. We ran tests to determine the hydraulic pressures in the automatic transmission such as TV (throttle-valve) pressure and clutch pressures.

We also ran official spark-advance curves. I think that was for the 1953 Chevrolet. Then, too, I helped quite a bit in the preparation of the test cars for the Southwest trip that year.

COLLINS: Are all of you thoroughly familiar with our organization chart?

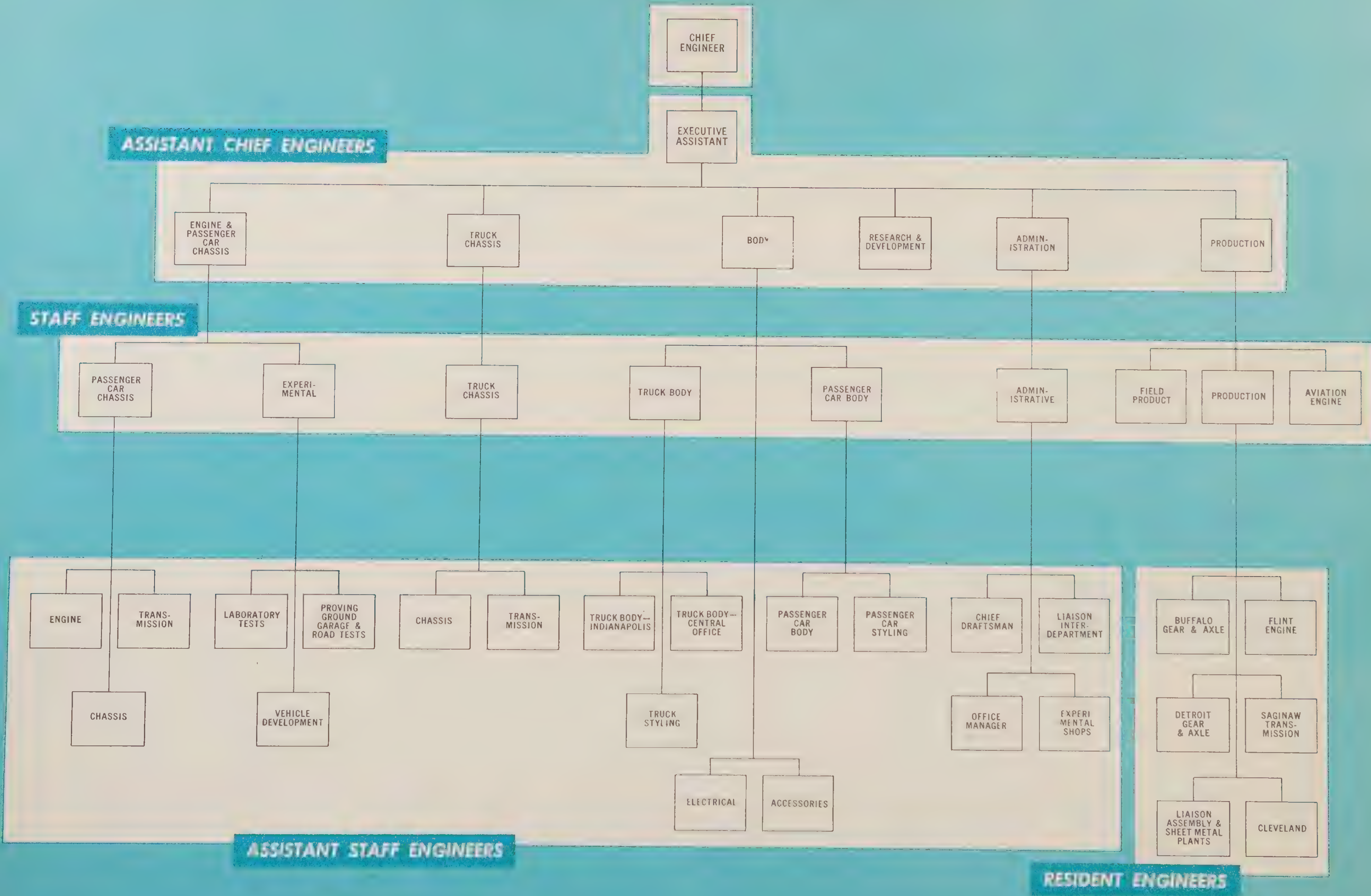
KONOPACKE: We've all seen it before and I know some parts of it like the back of my hand. But other parts are a bit hazy.

COLLINS: Well let's run through it quickly so that you will have a concrete idea of how all this fits into the total picture.

There are four levels of authority represented: (Fig. 1) The chief engineer, the assistant chief engineers, the staff engineers, and the assistant staff engineers. You will notice that at the staff and assistant-staff levels responsibilities are more specialized, while at the assistant-chief level, there is broad direction of many complementary activities.

The assistant chief engineer-in-charge

CHEVROLET ENGINEERING ORGANIZATION



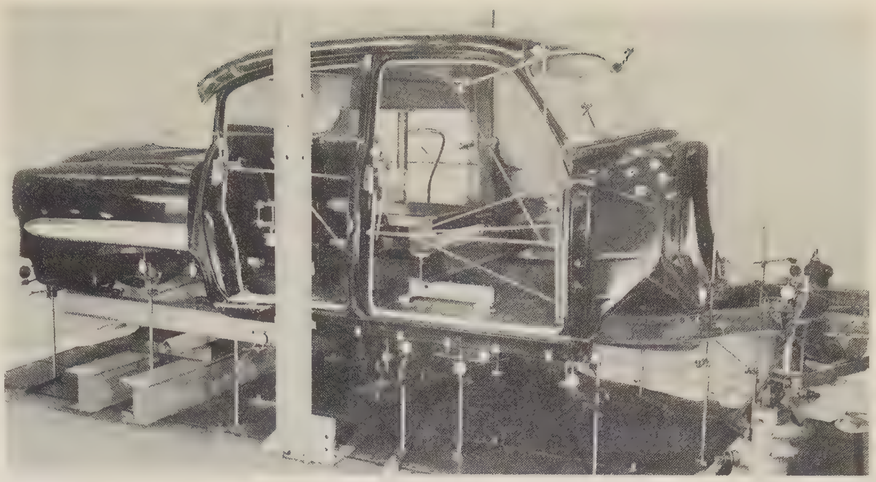
of Engines and Passenger Car Chassis, like some others, has charge of more than one Section. His first Section, Passenger Car Chassis, is divided into three Groups: the Engine Group, which is responsible for the design of all components of the engines, both passenger car and truck; the Transmission Group, which is responsible for the design of passenger-car transmissions, both standard and automatic; and the Passenger Car Chassis Group, which is responsible for the design of the frame, the front and rear suspensions, the steering control, the rear axle, and all the other chassis items. It was this Section, Dave, which originated the work you were doing in the drafting room.

The Experimental Section, also under the assistant chief engineer-in-charge of Engines and Passenger Car Chassis, is divided likewise into a number of Groups. You are already familiar with the Laboratory and have seen that it is equipped to conduct tests of various kinds on any part or assembly of either a passenger car or truck. Similarly, there is no need to elaborate on the function of the Proving Ground Garage and Road Tests Group for you gentlemen. You already have been there.

But you may not be as familiar with the Vehicle Development Group. The engineers in that Group work on any number of special projects dealing with any part of the vehicle, but primarily with the vehicle as a whole. Lately, they have been doing a great deal of work on sound and vibrational analysis of the assembled vehicle. You may have seen them at work in the chassis roll room at the Laboratory or you may have seen one of their test cars full of the elaborate equipment they use. They are particularly interested in problems which do not occur when the engine, transmission, or chassis are tested separately, but appear when the major assemblies are joined together.

The next Group on our chart is under the assistant chief engineer-in-charge of the Truck Chassis. Since frames, transmissions, and rear axles vary widely according to the size of the vehicle and its intended use, you can see that this Group has a very complex and important job. For instance, where we have only one wheelbase for all our regular passenger-car models, and another for the Corvette, we design trucks with eleven different wheelbases. Fitting the truck to the job requires an almost infinite number of variations in combinations of axles, transmissions, springs, tires, and innumerable other components of the trucks.

Fig. 1 (Left)—Organization of Chevrolet Motor Division's Engineering Department showing the four levels of authority and responsibility.



Beaming-test setup for a frame and body combination at the Chevrolet Experimental Laboratory. The frame is rigidly supported on knife edges placed at the rear-axle centerline and the steering-knuckle bolts. A load is then applied through the structure mounted in the body cavity and the deflection is measured by the dial indicators.

Moving on, we come to the Body Sections. You will notice here that both the Truck and the Passenger Car Body Sections have a Styling Group. You may wonder at this, in light of the fact that the styling of the Chevrolet is done by the General Motors Styling Section. But that isn't all the job. Obviously, there must be a means of control and communication between styling and engineering. Engineering is reluctant to impose its wishes on styling for fear of inhibiting the stylist. Rather, we express our views in the form of interest in certain features of the clay models or even the renderings (elaborate colored drawings of the first design sketches). This interest is usually taken as mild approval. Thus, we influence but do not guide styling through the styling engineer. The styling engineer aids in other ways. He points out the structural requirements of the body which is being styled or any other factors which are obvious to the engineer but outside the interest of the stylist. Finally, when the styling is completed and approved, the styling engineer releases the design to the appropriate production-design groups and maintains control over their work.

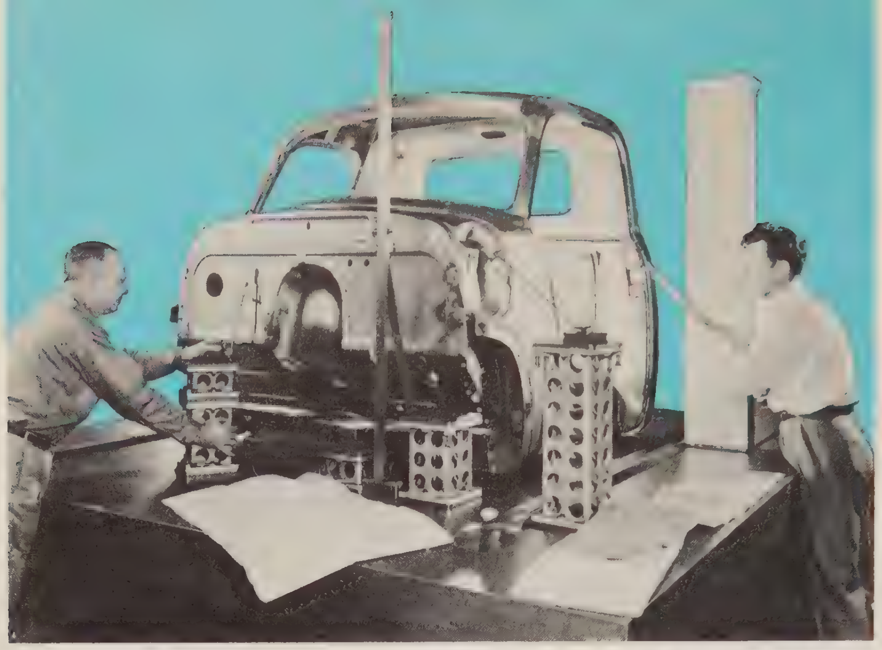
The Truck Body Section divides its production-design responsibilities between two Groups, one at Central Office here at Detroit and the other at Indianapolis. The Central Office Group is responsible for the truck cab, sheet metal, and trim. The Indianapolis Group is responsible for the design of panel bodies, pick-up boxes, canopy bodies, suburban bodies, platform bodies, and any special bodies which are modifications of these bodies.

You were assigned to the Truck Body Groups weren't you, Charles?

OLIVER: Yes, I went to Indianapolis—the Commercial Body Plant in Indianapolis. I spent the greater part of the time in the layout room where I did get into considerable design of truck bodies. I also did a minor design problem on a new latch mechanism which was to be interchangeable in a number of different doors. Then I did about a month in the Experimental Department. They build mock-ups of new ideas and designs and they also test existing designs. They were building a proposed pick-up box for future use. It was quite a nice deal—very nice from a styling standpoint.

COLLINS: I can see that you got a pretty good idea of how much work goes into our truck bodies.

Passenger-car bodies are another matter. Whereas Chevrolet manufactures its own truck bodies, it purchases its passenger-car bodies from the Fisher Body Division of General Motors. However, we do manufacture the fenders, hood, and bumpers which, for our purposes, are not considered part of the body. Therefore, we need the Passenger Car Production Design Group for this work as well as to maintain liaison with Fisher



Truck cab on the surface plate at the Indianapolis Commercial Body Plant. The engineer is making a design check to determine whether the production parts and the assembly conform to the blueprints.

Body. The Passenger Car Styling Group has much the same function as the Truck Styling Group.

The last two Groups in the Body Section are the Electrical and the Accessories Groups. I don't think it is necessary to say anything more about them since the names are self-explanatory.

The last Design Section, but one of the most important, is Research and Development. The Research and Development Section conducts studies leading to the development of new and advanced vehicle designs and perfects these designs to the point where they may be turned over to the Production Design Group. A recent example of this work was the design of the chassis for the Chevrolet Corvette.

The next Section, Administration, provides services which are necessary to the work of the Department as a whole; such as drafting, records, experimental fabricating, and interdepartmental liaison. It also is responsible for the interpretation and execution of company policies within the Engineering Department.

Let us dwell on these services for just a few moments since you will make constant use of them.

The Drafting Group, with which you spent some time, provides the drawings for the experimental building and testing programs conducted by any of the design sections as well as those accompanying the release of a design for production.

The Drafting Group is made up of a number of smaller groups, each headed by a supervisor, to work together with project and design engineers on particular components of the product.

After drafting has been completed, the design may be sent to the Experimental Shops Group for experimental fabrication and assembly in preparation for testing. To perform this work, the Shop Group has machine, forge, and stamping facilities, as well as pattern, sheet-metal, paint, and trim shops.

The writing and distribution of the necessary engineering records, specifications, and parts lists are supervised by the office manager. He also directs personnel activities.

The Interdepartmental Liaison Group maintains Engineering's contacts with the Sales, Advertising, and Public Relations Departments and provides them with any technical assistance they might require. Its other duties are to furnish guidance to the Design Sections in any

Assembling the front-end sheet metal at the Flint Assembly Plant. The Assembly Plant liaison engineers make pre-production checks of this assembly to insure proper fit of the parts and to devise the simplest and quickest assembly method.

matters pertaining to patents, legal matters, or new devices.

Now we come to the Section with which you have spent more time than any other, the Production Engineering Section. As you may have deduced by now, the Production Engineering Section maintains close contact between the Design Engineering and Production people so that the designs of all parts are suitable for Chevrolet's high-volume production and so that they are not unnecessarily difficult to make or assemble.

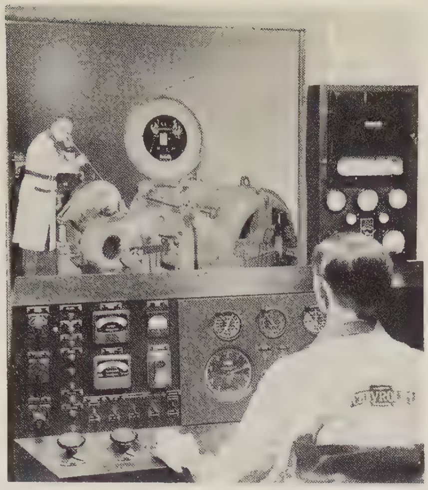
The best means to accomplish these purposes is to have the production engineers in residence at the various manufacturing plants. You have worked with some of these groups, haven't you Bill?

KONOPACKE: Yes, I went to the Flint Manufacturing Plant after I left the Proving Ground at Milford. The first week—well, we just learned to get around the plant a bit. It's quite a spread-out affair. Then I went into the dynamometer room and worked under Joe Hein (foreman of the Engineering Test Laboratory). While I was there, we were running tests on various designs for the cam gear. We tried nearly everything—new materials, different helix angles for the gears, and different pitch angles. I don't know how many different things we tried. If the samples lasted 100 hours at 4,200 rpm—that's equivalent to 85 mph—they passed the test.

I worked for about six weeks in the dynamometer room and then I did some inspection work with Ray Zimmerman (dynamometer test operator). After the engines were run through the durability test, we tore them down and checked the wear on certain parts—things like the wear on the valves and the pistons—and we measured the piston bores. That was very interesting work.

But I liked it best at Cleveland Transmission where I was under B. R. McRitchie (resident engineer), Bill Wallace, and Jack Hickey (senior project engineers). I was assigned first of all to work in the Quality Control Section. I worked with the converter man first. We went out on the line and I watched them assemble a converter. Then we took one off the line and gave it a complete check.

I went through the whole Powerglide transmission like that—from the converter to the planetary-gear set, the clutch, the governor, the main valve body, and all the other parts of the transmission.



Dynamometer tests on the Powerglide automatic transmission being conducted by the resident engineers at the Cleveland Transmission Plant. The man in the test cell is checking for noise by the use of a *sounding rod.*

COLLINS: You seem to have had a good time there.

KONOPACKE: In my opinion, Cleveland Transmission is one of the best plants. The men there are very good and they took me in as one of their own. They treated me very well and I enjoyed it there.

COLLINS: I'm confident that when you are better acquainted with the rest of the men in the organization, you will feel the same way about them.

Where were you assigned, Charles?

OLIVER: I went to the Flint Assembly Plant. The work was quite variable there. We did some work in quality control, some trouble shooting, and some work on engineering-change requests.

I did quite a bit of work on body-mounting procedures for the Assembly Plant liaison engineers. First, we determined the effect that internal stresses have on a body. We found that stresses are observable as *spring up* when the body is removed from the body truck pads and their ultimate effect is to distort the door openings and make the fitting of the front-end sheet metal difficult. Refitting doors or adjusting the fitting of the sheet metal could be costly and time-consuming.

We studied methods of adjusting the pads on the body trucks, observed methods of checking and shimming the frame to receive the body and I think we came up with some good answers to problems of this type.

COLLINS: You'll be seeing a great deal more of that type of work done in the future. A lot of man-hours are spent in assembling vehicles and with just a little more study we ought to be able to reduce that time by a considerable amount. After all, we can't be content with just having the assembly go together without interference; we want it to go together in the fastest possible time. We can make a lot of improvements through studies like yours.

Dave, what did you do while you were at Flint Assembly?

MARTENS: Oddly enough, the thing that sticks out in my mind is the time I went out into the OK Lot to see if the ignition key stuck. I couldn't quite see spending all that time doing that sort of thing, although I realize somebody has got to do it if they have sticking ignition keys.

COLLINS: What conclusion did you reach? Did you think it was a matter to be concerned with or just an isolated case?

MARTENS: I couldn't find any more cases like it. It must have been one of those things that just happen once.

COLLINS: This business of quality checks may seem insignificant, but it is right there that you preserve your customer good will. That's a valuable asset.

MARTENS: That's true.

COLLINS: We double check quality through the field product engineer who is, as you can see here, a member of the Production Engineering Department. He serves as a liaison between the Engineering Department and the Chevrolet Service Department and analyzes and investigates their reports of any difficulties in the hands of the owner. If he detects any serious difficulties, he advises us and we move as quickly as possible to determine the cause and provide an adequate remedy.

MARTENS: Yes, a lot of stress was laid on things I don't consider important in an automobile, such as the correct fit of the chrome trim. Chromium trim is a means of selling a car and doesn't have a thing to do with the operation of the automobile. Therefore, to me, it doesn't amount to much. If it were an engine problem, or a chassis problem, that's something else again. Maybe the springs don't ride quite right. That's a functional part and not just an appearance item. I know that an automobile is sold largely on appearance but they don't sell automobiles to me that way.

COLLINS: You're obviously an en-

ORGANIZATION OF A PROJECT

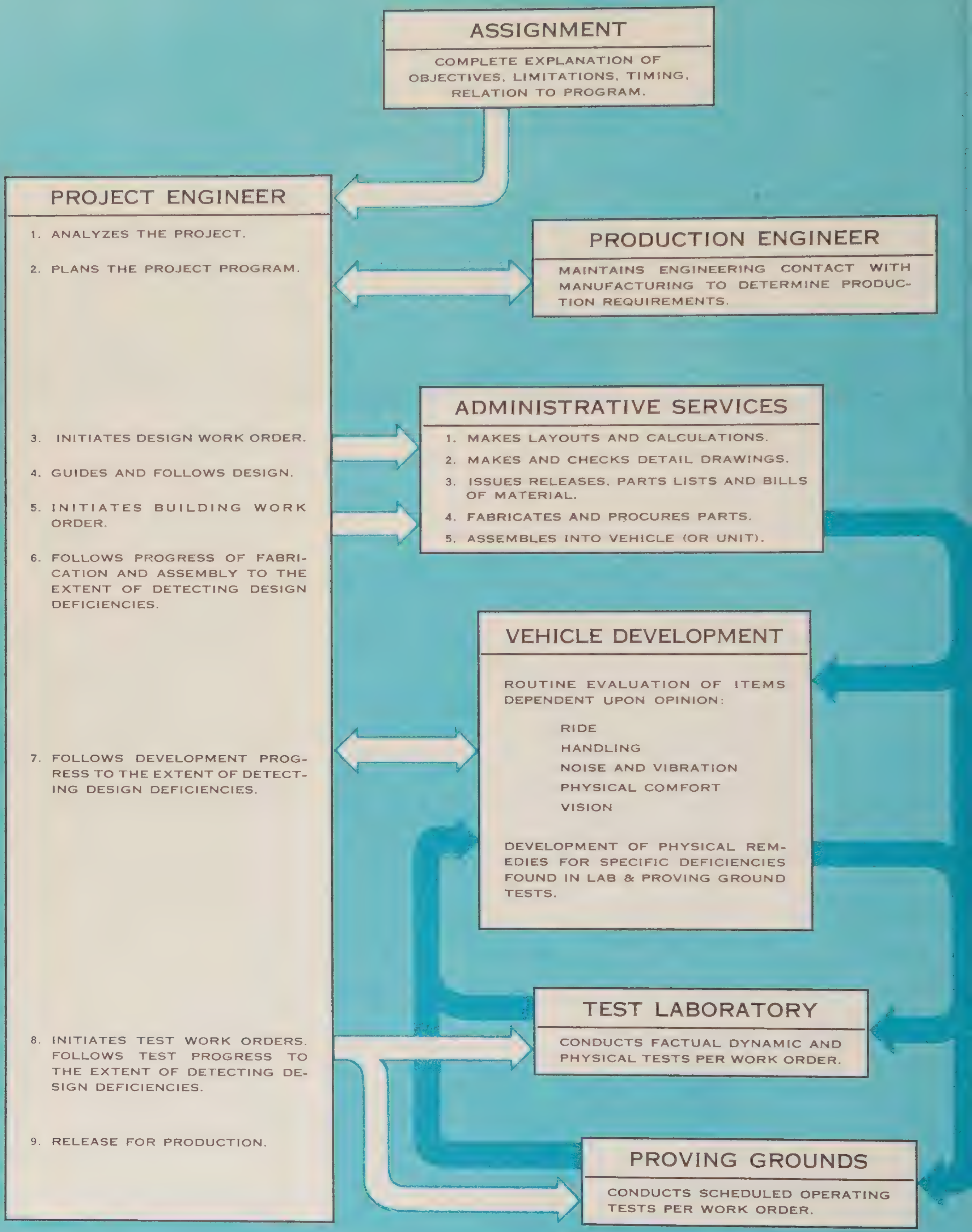
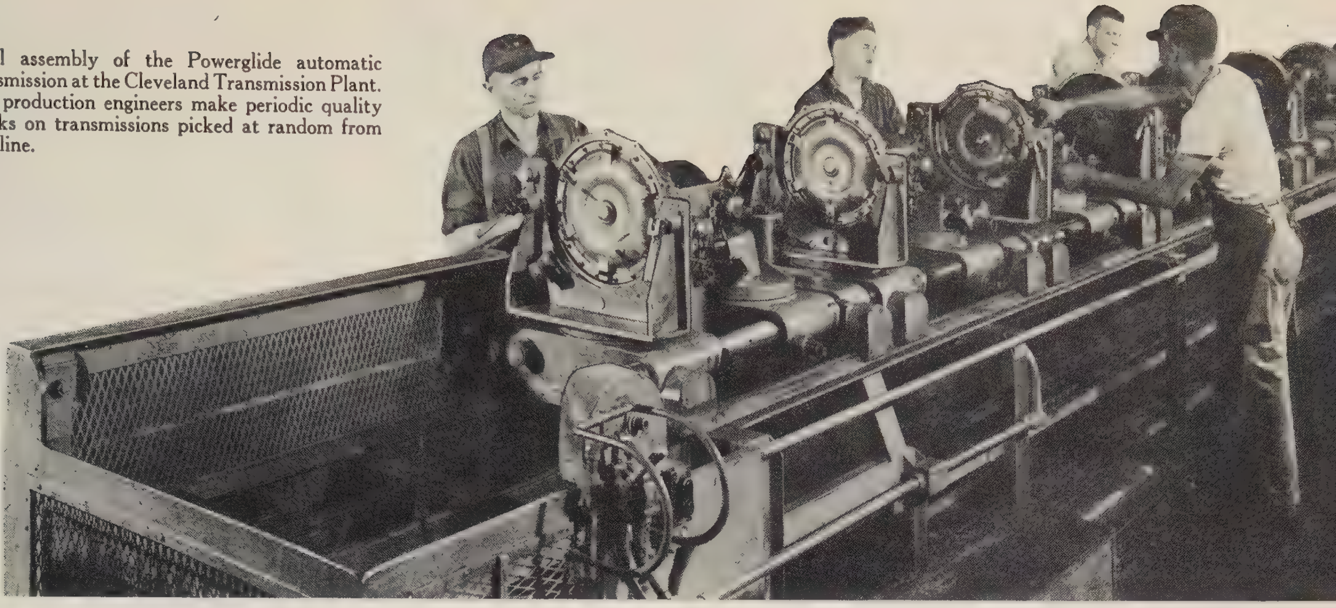


Fig. 2—Flow chart indicating how the work of the various sections is integrated in the completion of a typical project assignment in the Chevrolet Engineering Department.



Final assembly of the Powerglide automatic transmission at the Cleveland Transmission Plant. The production engineers make periodic quality checks on transmissions picked at random from this line.

gineer's engineer. But I'll bet Charles could give you a good argument on that subject. How about it Charles?

OLIVER: I think Dave's attitude is more a reaction against chrome gingerbread than anything else. On that point, I'm in perfect agreement. But I think he will agree that the judicious use of chrome trim can accent the beauty of the basic lines of the body.

Chrome has strictly functional uses, too. For instance, you have a difficult job keeping paint on a bumper. Chrome is the preferred finish from both an appearance and a functional point of view. Or, take the strip of chrome trim which runs along the side of the body, half way up the side of the door and fenders. True, it contributes to an appearance of length in the car but it also protects the painted surface of the body. The next time you are in a parking lot, notice how many times an inconsiderate parker will bang his door into the adjacent car. The door and fender molding serves as a rub rail which protects your finish.

MARTENS: I hadn't looked at it that way.

COLLINS: This brings us to the last Section of the organization chart which is the Aviation Engine Project. This Section is composed of a number of smaller groups which we have not shown here. Together, they are responsible for maintaining the overall quality of the aircraft engines we produce for the government under a license agreement with the Wright Aeronautical Division of the Curtiss-Wright Corporation.

Now, there is just one more thing I would like to show you. This is a flow chart (Fig. 2) which was worked out by Arthur Altz, our assistant chief engineer-in-charge of Administration. It is a well-rounded picture of how all of the sections integrate their efforts and how the administrative services contribute to the development of the product.

The project begins when the assignment is defined by the Engineering Staff and given to the project engineer for execution. Now this is a pretty remote way of putting it so let us look at a recent project, the Corvette chassis. What we had in mind was to build a sports car with a plastic body in time for the GM Motorama at the Waldorf in January 1953. We started in the middle of the previous May, so that meant we didn't have very much time.

When you look the field over, there seem to be dozens of different definitions of a *sports car*. But I think Maurice Olley, the director of the Research and Development Section, grasped the intent of the sports car when he defined the specifications of the Corvette chassis. It was to be quick in handling, have a low center of gravity, a close to 50-50 weight distribution between front and rear, and a smooth, yet firm, suspension. These features gave us a car which had the "feel" associated with the sports chassis.

The project was then distributed among the responsible project engineers who were further advised to use as many current-production parts as possible to keep the cost within reason and to arrange the work so as not to interfere with the work on the regular models. Does that give you a clearer idea of the nature of an assignment?

After the project engineer has received his assignment, he analyzes the project and plans his program. If necessary, he may consult the production engineer at any time or in any phase of his program to learn manufacturing requirements. Thus, every precaution is taken to insure that the design will be a success from both a design and a production point of view.

Having formulated his program, the project engineer writes a design work order requesting that a layout be drawn. During the layout stage, he guides and follows the design and when he is satisfied, he orders detail drawings made from the layouts. While this work is in progress, other groups of the administrative services are making up the experimental releases, parts lists, and a bill of material. With the experience you have had, I think you are able to follow the rest of the flow chart.

MARTENS: It seems clear enough, but I don't see the reason for the solid flow lines.

COLLINS: Yes, I should have explained that. The flow lines which are outlined signify the flow of information and guidance, while the solid lines signify the paths taken by the experimental models after they have been built and assembled by the experimental shops.

If there are no more questions, I think we'll bring our meeting to an end. Before you gentlemen leave, I want to tell you that I am very pleased with your interest in this work and the progress you have made. You have done a good job.

The Chemical and Physical Properties of Brake Fluids for Safe Vehicle Operation

By FRANCIS J. MARKEY
Moraine Products Division

To stop the antiquated horse-drawn vehicle, a shoe was applied by a lever and fulcrum against the outer rim of the wheel. Today, practically all vehicles are equipped with brakes operated by hydraulic pressure and effective at all four wheels. The safety of the driver, passengers, pedestrians, other vehicles, and public property depends on the ability of these brakes to control and stop the motion of the vehicle. Failure of the brakes to react instantaneously can cause serious injury or loss of life. Consequently, the brakes, under all conditions of temperature and load, must be capable of stopping the vehicle quickly. Brake fluid, the medium through which force is transmitted from the driver's foot on the brake pedal to the brake shoes, must possess the necessary chemical and physical properties that will allow maximum work output and the largest factor of safety.

From engineers' specifications: a brake fluid that never fails the foot pedal

HYDRAULIC brakes are used extensively on present-day cars and light trucks because of their relatively simple construction and the even, balanced braking action that this type of brake provides at all four wheels of a vehicle. Hydraulic brakes utilize the pressure of a liquid (hydraulic pressure) to force the brake shoes against the brake drums which are part of the wheel construction causing a frictional drag which reduces the speed or stops the motion of the vehicle. When the driver's foot depresses the brake pedal, pressure is built up in the master hydraulic cylinder which contains brake fluid. Following Pascal's principle—in a closed system additional pressure introduced at any point is distributed equally and undiminished to all other points in the liquid—this pressure is transmitted to the brake shoes through a system of steel tubes which carry the brake fluid to the operating cylinders on each wheel of the vehicle. These cylinders, in turn, convert the transmitted hydraulic pressure into mechanical power which expands the brake shoes and checks the motion of the vehicle. Brake fluid, then, serves as the medium through which force is transmitted from the brake pedal to the wheels. Consequently, correct hydraulic-fluid selection is of extreme importance if the braking system is to function with maximum efficiency and a high degree of safety.

Brake-Fluid Properties

Water was used in the first hydraulic systems—the word "hydraulics" itself is based on the Greek word for water. At present, water is used only in large, commercial hydraulic installations geared for high pressures and low operating speeds as, for example, large freight elevators. Usually, a small concentration of emulsifying oil (2 to 3 per cent by weight) is added to the water as a protection against rust and corrosion. In most hydraulic systems, however, oil is used as the hydraulic medium since water causes corrosion, has poor lubricating qualities, and changes easily from the liquid to the solid or gaseous states—all undesirable qualities in a hydraulic medium.

Besides the two necessary qualities of incompressibility and fluidity, the *ideal* brake fluid should possess a number of other definite characteristics to insure safe and satisfactory brake performance.

Chemical Stability

Brake fluids must be chemically stable. Because they are hydrocarbons, oils are prone to undergo undesirable chemical changes under severe operating conditions or when exposed to air. For example, when a system operates at high temperatures for a prolonged period of time and is exposed to air, the oil may break down chemically to form insoluble sludges, gums, and other deposits which clog openings and reduce lubrication. The ideal brake fluid should be unaffected by air, salt, water, and other impurities that might find their way into the brake system.

Non-Acidity

The ideal brake fluid should be non-acidic and non-corrosive. It should not attack the metal or rubber components of the brake system, nor should it damage the car enamel or paint finish if accidentally spilled on the car.

Lubricating Power

It is a law of physics that, when motion occurs between surfaces in contact, friction tends to oppose the motion. In a hydraulic system, however, when pressure forces the liquid between the moving surfaces, the liquid forms a thin film between these surfaces and allows them to slide over one another—the area is lubricated. To prevent the parts of the brake system from wearing quickly, the ideal brake fluid should have high *film strength* or high resistance against being forced out from between surfaces when spread in a very thin layer. If only partial oil films are present because the fluid has drained or has been squeezed out, harmful metal-to-metal and rubber-to-metal contact occurs.

Viscosity

Viscosity is defined as the tendency of a fluid to resist flowing. Thinner liquids which flow easily are the less viscous. Viscosity varies with the temperature; fluids flow less easily as their temperature is lowered. The ideal brake fluid should be viscous enough to give a good seal at the valves and pistons but should not be so thick that it will not flow—resulting in power loss and excessive wear on parts. A fluid with too low a viscosity may lead to rapid wear of moving parts because it is a poor lubricant.

Pour Point

The *pour point* of a fluid is defined as the temperature at which a fluid will solidify or congeal. The presence of a wax in the brake fluid affects the pour point. Dissolved in the fluid at ordinary tempera-

tures, when the fluid is chilled, the wax precipitates in the form of minute crystals which grow in size and number as the temperature is lowered. These crystals form a lace-like structure which retards the flow of the fluid. The ideal brake fluid should have a pour point much below its minimum operating temperature.

Flash Point

Flash point is the lowest temperature at which a liquid gives up sufficient vapor to ignite momentarily when a flame is applied. A high flash point is indicative of low evaporation and of a high boiling point.

Boiling Point

Since hydraulic-brake action is, for the most part, dependent on the brake fluid remaining in the non-compressible fluid state, the brake fluid's boiling point is its most important property in regards to safety; the higher the boiling point of the brake fluid the greater the factor of safety. In the early automobiles, the wheel cylinders were cooled easily because they were located away from the brake and in a cool-air stream. In present models, the wheel cylinders are nested within the brakes; thus, the fluid is subjected to high temperatures.

BRAKE-FLUID SUBSTANCES

Lubricants	Diluents	Inhibitors
Castor oil	Methyl alcohol	Borax
Blown castor oil	Ethyl alcohol	Calcium nitrate
Modified castor oil (reacted with glycols)	Propyl alcohol	Magnesium nitrate
Ether of polyglycols	Butyl alcohol	Sodium nitrate
	Diacetone alcohol	Petronate
	Isobutyl alcohol	Sodium tetraborate
	Methyl amyl alcohol	Phenyl morpholine
	Cellosolve	Diphenyl propane
	Methyl Cellosolve	Catechol
	Butyl Cellosolve	Phenylalpha naphthylamine
	Carbitol	
	Methyl Carbitol	
	Butyl Carbitol	
	Methoxy-methoxy ethanol	
	Ethylene glycol	
	Propylene glycol	
	Hexylene glycol	
	Dipropylene glycol	

Table I—A listing of many of the substances used in brake fluids.

Development of Brake Fluids

Originally, automobile brakes were operated mechanically. The introduction of four-wheel brakes, softer car springs, and heavier automobile bodies necessitated finding a method of applying pressure *equally* to all four brake shoes. The hydraulic control giving equal and undiminished pressures throughout a liquid provided the required solution.

Before a usable brake fluid was developed, however, engineers had to solve numerous problems in brake design. The cylinders containing the brake fluid had to be sealed tightly to prevent the fluid from seeping away when the brakes were in use or idle. The early hydraulic-brake systems used seals made of rawhide. With this particular type of seal a light mineral oil was used as the hydraulic medium.

Next, brake engineers fashioned the conduits which carried the fluid from the master cylinder to the operating cylinders on the wheels from special, flexible, rubber-lined hose as rubber is able to withstand a large number of wheel deflections. But the rubber absorbed the mineral oil, became swollen, and deteriorated.

The next step was to find a fluid that was compatible with both leather and rubber. Engineers tried glycerine-base hydraulic fluids which were mixtures of glycerine and water and glycerine and alcohol. Tests showed that these mixtures proved unsatisfactory in service. The water corroded the pistons and the cylinders causing leaks, the alcohol evaporated changing the low-temperature characteristics of the fluid, and the glycerine became gummy allowing the brake parts to stick.

At that time, the only available fluid that gave satisfactory results was a mixture of castor oil and a commercial ethyl alcohol in approximately a 50:50 ratio. The ethyl alcohol was added because pure castor oil alone had too low a viscosity at low temperatures and would not flow.

Soon after these hydraulic systems were put into use, still other difficulties plagued the engineers. The rawhide seals cracked because of the heat produced after the brakes had been used extensively. After experimenting with various designs and materials, specially compounded rubber cups were used as seals.

This addition of still more rubber to the brake system provoked a chemical change in the fluid. The small acid content of the castor oil-ethyl alcohol mixture combined with the sulphur in the rubber (rubber manufacturers used sulphur when vulcanizing the rubber cups) and formed an acid which corroded the brake system. This situation was relieved by the addition of potassium hydroxide *KOH*, a neutralizing agent.

Changes in Automotive Design Affecting Brakes

Major innovations in automotive design in the past two decades have dictated still more changes in hydraulic-brake systems. One of these design changes was the modification of the large-diameter, open-spoked wheel of the earlier models to the small, solid-disc-type wheel on present-day automobiles. The brake-shoe and drum diameters necessarily had to be reduced along with the wheel size. Furthermore, the flow of cooling air to the brakes has been restricted by the introduction of lower automobile bodies and fenders, the addition of fender skirts, and the fact that the present wide wheel rims and tires completely surround the brake drum.

The adoption of automatic transmissions and the increase in engine horsepower have added to the requirements of the brake system. Better highways, increased speed, power steering, and greater riding comfort have put increased demands on the brakes. This meant doing more brake work in less space and with a reduction in the amount of cooling air provided to the brakes. Thus, all the brake parts, including the brake fluid, are subjected to higher and higher temperatures. Should the temperature of the wheel cylinders rise above the boiling point or the vaporizing point of the brake fluid within the cylinder, a *gas pocket* will form causing possible complete brake failure without warning to the driver.

By pumping the brake pedal, the driver may be able to force fluid back into the wheel cylinders and compress the gas into a fluid state, thereby restoring normal brake action. Also, cooling of the brake parts below the boiling point of the brake fluid will cause the gas to condense, form a vacuum, and pull fluid back into the cylinder, restoring brake action.

The temperature of master cylinders, unlike that of the wheel cylinders, is not directly related to brake work but instead is related to the temperature of the surrounding air and the mounting brackets. The temperatures of master cylinders have been rising considerably in the past few years due to the master cylinders being mounted on the fire wall over high-powered engines and due to power steering, automatic transmissions, and exhaust pipes closely surrounding the master cylinders in the conventional location.

It is not uncommon for the brake fluid in the master cylinders of today's cars to reach 200° F. Should the brake fluid boil in the master cylinder, brakes will fail without warning, and the only way that brakes can be restored is for the master cylinder to cool. Pumping the pedal will not remove the vapor lock.

Mountain driving puts increased duty on brakes, power-steering gears, automatic transmissions, and rear axles and engines. Brake fluids, therefore, are subjected to high temperatures under such service. With every 2,000-ft increase in altitude, the atmospheric pressure drops approximately 1 psi. For every pound reduction in atmospheric pressure the boiling point of the brake fluid drops

Examples of Actual Brake-Fluid Compositions

Moderate-Duty Fluid #1	Per Cent
Reacted castor oil (equal parts of castor oil and polypropylene glycol)	30
Butyl alcohol	55
Propylene glycol	15
Heavy-Duty Fluid #2	
Ether of polyglycol	26
Carbitol	37
Butyl Cellosolve	37
Catechol	0.1
Sodium tetraborate	0.5
Sodium nitrate	0.01
Phenylalpha naphthylamine	0.2

Table II—Typical examples of the percentages of substances used in brake fluids.

BRAKE-FLUID SPECIFICATIONS

Tests	Test Limits: S.A.E. 70R2 Moderate-Duty	S.A.E. 70R1 Heavy-Duty	Ideal Specificatio
Viscosity (at —40° F) (maximum centistokes)	1,800	1,800	500
Viscosity (at 130° F) (minimum centistokes)	3.5	3.5	20
Cold Test (6 days at —40° F)	Flow in 5 sec No stratification Slight precipitation	Flow in 5 sec No stratification No precipitation	
Freezing Point (6 hr at —60° F)		Flow in 5 sec	Flow immediatel No stratification No precipitation
Boiling Point (minimum)	230° F	300° F	500° F
Flash Point (minimum)	100° F	145° F	Non-inflammable
Water Tolerance (3½ per cent water at 120° F and —10° F)	No stratification Slight precipitation		
Water Tolerance (3½ per cent at 140° F and —40° F)		Flow in 5 sec No stratification No precipitation	
Water Tolerance (10 per cent water at 200° F and —60° F)			Flow immediately No stratification
Neutrality pH	7.0 to 11.0	7.0 to 11.0	7.0 to 8.0
Neutrality pH (after corrosion test)	7.0 to 11.0	7.0 to 11.0	7.0 to 8.0
Stability (295° F for 6 hr) (minimum boiling point)		295° F	
Stability (225° F for 6 hr) (minimum boiling point)	225° F		
Stability (495° F for 6 hr) (minimum boiling point)			495° F
Rubber Swelling (120 hr at 158° F)	0.005 in. to 0.050 in. Not tacky	0.005 in. to 0.050 in. Not tacky	
Rubber Swelling (240 hr at 400° F) Synthetic Cups			0.005 in. to 0.03 Not tacky
Compatability 50-50 Mixtures (24 hr at 140° F and —30° F)	No stratification No precipitation	No stratification No precipitation	No stratification No precipitation
Lubrication (Stroking Test) (158° F, 500 psi, 150,000 strokes)	No leaks, corrosions, galling	No leaks, corrosions, galling	
Lubrication (Stroking Test) (400° F, 1,500 psi, 500,000 strokes)			No leaks, corrosions, galling
Lubrication (Pump Test)			Equivalent to S.A No. 10 oil
Residue (14 days at 158° F)	No corrosion, gum, or residue in wheel cylinder	No corrosion, gum, or residue in wheel cylinder	No corrosion, gu or residue in whe cylinder
Evaporation (48 hr at 210° F)	85 per cent	80 per cent	20 per cent
Corrosion (120 hr at 210° F) (maximum mg/sq cm)			
Tinned iron	0.2	0.2	None
Steel (S.A.E. 1010)	0.2	0.2	None
Aluminum (S.A.E. 24)	0.1	0.1	None
Cast iron (S.A.E. 111)	0.2	0.2	None
Brass (S.A.E. 70B)	0.5	0.5	
Copper (S.A.E. 71)	0.5	0.5	
Odor			Odorless
Attack on lacquer and enamel			No attack
Foaming			Very low
Color			Distinctive

Table III—A listing of S.A.E. brake-fluid specifications giving moderate-duty and heavy-duty specifica and comparing both to the ideal brake-fluid specifications.

about 3° F. Consequently, there is a danger of brake failure when using low boiling-point brake fluids during mountain driving.

Continuing changes in brake design and brake materials decree that the brake fluid—in constant contact with the internal parts of the system and responsible for the lubrication of the moving parts—must have definite chemical and physical properties to assure safe and dependable brake action throughout a wide range of operating conditions.

Brake-Fluid Specifications

Prior to World War II there was no published set of specifications for brake fluids based on actual brake-service requirements. In 1942 the U. S. Army Ordnance, together with the War Engineering Board, the Coordinating Research Council, and the Society of Automotive Engineers, set up a table of specifications for brake fluids to be used in Ordnance vehicles. This listing, called Ordnance Brake Fluid Specification 2-111, encompassed all the conditions that hydraulic brakes could encounter anywhere in the world.

The post-war increase in serious accidents because of brake failures was traced to the fact that unsuitable solutions were sold as brake fluids and also low-priced, war-surplus mixtures were being used in hydraulic systems, damaging brake controls. The requirements contained in the Ordnance 2-111 Specification were for heavy-duty brake fluids that used materials deemed too costly and scarce for commercial use. Consequently, the Society of Automotive Engineers in 1945 set up a committee of experienced brake and chemical engineers to prepare *moderate-duty* and *heavy-duty* brake-fluid specifications giving the necessary properties for brake fluids suitable for moderate-duty service in passenger cars and light trucks and also fluids suitable for heavy-duty service under severe passenger-car and truck operating conditions.

The S.A.E. specifications, directed to all automotive manufacturers and sales and service organizations connected with hydraulic brakes, were determined from service records, field-performance records, and physical and chemical tests.

Brake-Fluid Compositions

In order for today's brake fluids to have the properties necessary to meet the performance requirements set up by the S.A.E. specifications, it is necessary that brake-fluid formulations use mixtures of many commercial chemical compounds. No single-component fluid has been found to be satisfactory.

Brake-fluid compositions usually can be separated into three parts: (a) lubricants (basic materials), (b) diluents (solvents, and (c) inhibitors (Table I).

The basic materials give the brake fluid body and lubricating properties, but the low-temperature viscosities of these materials are too high. The lower alcohols (those containing a low number of carbon atoms; for example, methyl alcohol and ethyl alcohol) are effective low-temperature viscosity reducers which do not harm the rubber seals and hose, but which fail to meet high-temperature requirements. The higher alcohols (those containing long chains of carbon atoms) and Cellosolves (commercial name for ethylene glycol monoethyl ether) usually give greater rubber swell than desired so the glycols (compounds containing two *OH* groups) are added to modify the rubber attack, to improve water tolerance, to solvate certain inhibitors, and also to lower the pour point. It is not uncommon to find three or four of the above listed diluents used in various proportions in today's brake fluids.

Castor oil (ricinoleic acid) is a very good lubricant for the metal components and the rubber cups, but it is difficult to find a solvent that will keep the oil from solidifying during prolonged exposure to low temperatures. Also, pure castor oil will oxidize and form gum. Castor oil, however, will react with glycol in the presence of heat and a catalyst (potassium or sodium hydroxide) to form a mixture of ricinoleates, and the reacted castor oil (glycol ricinoleates) has a lower solidification point than unadulterated castor oil and has less tendency to form gums.

The synthetic lubricants, like ether of polyglycol, have excellent low-temperature viscosities, do not oxidize and form gums, have little effect on rubber, and can be made in various viscosities. Both water-soluble and non-water-soluble synthetic lubricants are being used in brake fluids.

All hydraulic-brake systems breathe as the brakes are operated and as they heat up and cool off. Thus, the brake fluid is subjected to air and moisture which can cause oxidation and corrosion of the metal parts. Inhibitors and anti-oxidants of the types listed in Table I are used in most brake fluids.

Two examples of actual brake-fluid compositions are given in Table II.

Discussion of Specifications

The S.A.E. specifications cover only non-mineral-oil hydraulic fluids. Non-mineral oil-type fluids, until the development of synthetic rubber-like materials, have been required for all automotive hydraulic-brake systems. The reason, as was shown earlier in this paper, is that mineral oil attacks natural rubber. At present, some truck manufacturers are producing hydraulic systems using a mineral-oil hydraulic fluid with synthetic-rubber conduits and seals.

Table III is a listing of the principal requirements of both heavy-duty and moderate-duty fluids and compares them with the specifications of an ideal brake fluid. A discussion of these requirements follows.

Viscosity: The temperature range in which commercial vehicles operate in the United States is from 130° F to —40° F. The higher the temperature the lower the viscosity and, consequently, the greater the chance for leakage. The ideal specification requires a minimum of 20 centistokes at 130° F but tests showed that with a minimum viscosity as low as 3.5 centistokes, if the seals and conduits are kept uncontaminated, the brakes will function properly. Actual tests on cars showed that brake fluids with a viscosity of more than 1,800 centistokes are too sluggish to give equalized brake pressures.

(The kinematic coefficient of viscosity based on the actual internal frictional resistance of a fluid is defined by the equation:

$$\nu = \frac{\mu}{d}$$

where

μ = absolute viscosity

d = density of the fluid.

The coefficient ν is given in the units of feet squared per second or centimeters squared per second. In the metric system the unit of kinematic viscosity is called the *stoke*, honoring the English mathematician Sir George Stokes who developed a method of measuring viscosity. A one-hundredth part of a stoke is a *centistoke*, the unit used in the S.A.E. specifications.)

Cold Tests: One of the chief failures of brake fluids has been the fact that they froze when the automobile was exposed to low temperatures for a lengthy period

of time. In arriving at the S.A.E. specifications, samples of brake fluids were exposed for 6 days at —40° F to make certain that the fluids meeting the other requirements would not solidify or form layers when subjected to low temperatures for a considerable period of time.

Boiling Point: The boiling points listed in the specifications are approximately the temperatures at which the fluid will boil in a hydraulic system with no static check-valve pressure to form enough vapor to cause the brakes to *lock.* A rise in the residual line pressure correspondingly raises the boiling point. With a pressure of 8 psi to 15 psi the boiling point is raised 15° F to 35° F. A high boiling point is important from a safety viewpoint as the brake fluid must remain in the non-compressible fluid state in order for the brakes to function properly. The 500° F minimum boiling point for the ideal brake fluid gives a wide margin of safety even with the rising brake temperatures on present automobiles.

Flash Points: Insurance companies desire high flash points because of the fire hazards in the handling and storing of quantities of brake fluids. While, theoretically, the ideal brake fluid should be non-inflammable, this property is not all-important from the standpoint of a performance requirement.

Water Tolerance: The presence of water in the hydraulic system should not adversely affect the action of the brakes. While it is not unusual to find up to 3½ per cent of water in the brake system, there is a danger that it will not be absorbed by the brake fluid and, at low temperatures, freeze and block the conduits. In addition, the presence of water may cause the stratification or precipitation of chemicals added to the fluid.

Neutrality: To protect the various metal parts of the system it is necessary that the fluid be neither too acidic nor too highly basic. The neutrality of a solution is given in terms of its *pH* which is defined as the logarithm of the reciprocal of the hydrogen-ion concentration in a solution. The pH of distilled water *HOH*, a chemically neutral solution because it is composed of equal concentrations of *H* ions and *OH* ions, is seven and is used as the standard. Any solution with a pH greater than seven is said to be basic and any solution with a pH less than seven is acidic. Solutions with a pH value outside the range listed in the ideal specifications would be too corrosive. The desired pH for an ideal brake fluid is from 7.0 to 8.0 which is a neutral or slightly basic solution.

Stability: Brake fluids must remain in the liquid state at all temperatures. Consequently, the *stability* of the fluid, its ability to remain in one physical state regardless of temperature and pressure changes, is an important property. The stability requirement states that the minimum boiling point of the fluid should not change more than 5° F after a sample of the fluid is subjected to high temperatures for six hours. Water was discarded as a possible hydraulic-brake medium because it changes easily from a liquid to a solid or a gas.

Although it is not possible to produce an oil that will not oxidize (since all oils will burn), most of the chemically unstable hydrocarbons, if correctly refined, can be eliminated leaving an oil of high stability with good heat- and oxidation-resistant properties.

Rubber Swelling: Natural-rubber cups were tested by being immersed in the fluid under test for 120 hours at 158° F, washed with ethyl alcohol, and measured. The size of the cup should not have changed after test more than 0.005 in. to 0.050 in. Because of the introduction of synthetic-rubber parts into the brake system and the present high brake-temperature trend, the rubber-swelling specification may require further revision.

Compatibility: Automobile manufacturers generally specify the particular type of fluid best suited for use with their hydraulic-brake systems and using another fluid or mixing two or more fluids may reduce the brake performance. In setting up the compatibility or miscibility requirement 50-50 mixtures were prepared and held for 24 hours at 140° F and —30° F. Then the mixtures were examined for signs of precipitation or stratification.

Lubrication: Improper or insufficient lubrication will cause wear in the moving parts of the system. Despite years of research, there is no established test or measure of the lubricating value of a fluid other than the results obtained by operating the systems under actual service conditions. The S.A.E. lubrication specifications were found by operating actual brake systems and checking for leaks and worn parts. Higher pressures on future systems will require still more exacting lubricating qualities.

Residue: Brake systems should not become corroded or gummed when stored for a long interim while still filled with brake fluid.

Evaporation: A small amount of fluid seepage and evaporation takes place in hydraulic systems. If there is less than 15 per cent of the oily base in the fluid after evaporation, increased wear usually results.

Corrosion: Brake fluids should not attack and corrode the metals in the brake system—steel, aluminum, cast iron, and brass.

Odor and Paint Attack: The ideal brake fluid should be odorless and should not damage paint and enamel. Present fluids have penetrating odors and all attack paint finishes.

Foaming and Color: The ideal fluid should have low foaming action. A distinctive color would aid in identifying a particular liquid.

Conclusion

The proper functioning of brakes is of such importance that some communities have definite regulations and laws stating that brakes, brake hose, and brake fluid must meet definite performance standards. Each of the minimum and maximum requirements included in the S.A.E. Brake-Fluid Specifications is practical and necessary if the driver is to get the highest performance and the greatest safety from hydraulic brakes. With the advent of synthetic rubber, higher brake temperatures, power steering, automatic transmissions, and higher-horsepower engines, engineers must continue to test and perhaps revise the present specifications.

Bibliography

Other related literature in this field includes the following:

CROUSE, W. H., *Automotive Mechanics* (New York: McGraw-Hill Book Company, Inc., 1946; 8th Edition), pp. 545-71.

DODGE, R. A., *Fluid Mechanics* (New York: McGraw-Hill Book Company, Inc., 1937).

......, *G.M. Standards*, Hydraulic Brake Fluid Specification GM-4653M.

......, *Basic Hydraulics* (Washington, D. C.: Standards and Curriculum Division, Training Bureau of Naval Personnel, 1945).

......, *S.A.E. Handbook* (New York: Society of Automotive Engineers, 1953), p. 292.

......, *Your Automobile—How to Understand It* (New York: Socony-Vacuum Oil Company, Inc., 1953), pp. 77-80.

Notes About Inventions and Inventors

By EUGENE W. CHRISTEN
Patent Section
Central Office Staff

From product improvement to granted patent

Each Division of General Motors is engaged in a ceaseless effort to improve the products that it manufactures and—equally important—each seeks new products that might be profitable to manufacture. A product cannot be improved without altering it in some manner. These never-ending changes provide the major portion of the activity of the Central Office Patent Section, for these modifications may involve patentable inventions and/or infringements on the patent rights of others. Product improvements and patent problems occasioned by these changes are not peculiar to General Motors; they exist in all competitive industries, regardless of size.

A Case Example

The following typical example presents a general picture of the manner in which product improvements are handled from a patent standpoint.

Suppose that one of the Divisions designs an improved carburetor and desires to manufacture it commercially. Liaison personnel at the Division first contact a designated patent attorney of the Central Office Patent Section and furnish him with a full disclosure or description of the improvements in the carburetor which, for the sake of illustration, might be the following items:

(a) An increase in the size of the idle-jet orifice
(b) A radically different accelerating pump
(c) A new linkage arrangement for the automatic choke.

The Division also informs the patent attorney of any prior carburetors of similar construction of which it is aware. The closest prior construction in this case is the carburetor now being manufactured at the Division.

Item a, being merely a change in size, immediately is exempted from investigation as it does not involve a patentable improvement on the present carburetor.

Items b and *c* are set up for investigation as to possible patentability and/or infringement.

The Role of the Searcher

An initial investigation is conducted by searchers in the Public Search Room of the United States Patent Office Library, Washington, D. C. The Central Office patent attorney furnishes the searcher with the relevant information on the carburetor and requests that a *patentability* (or novelty) *search* and an *infringement search* be made on *items b* and *c*, noted above.

The Patent Office Library contains publications and collections of foreign patents as well as complete information on United States patents. For patentability and infringement searches, the searcher generally will restrict his investigation to the United States patents. The Search Room has about 2,670,000 United States patents classified into approximately 45,000 subclasses. These subclasses are formed by grouping together inventions that have like functions or that produce like products. The subclasses also are grouped by general subject matter into 307 classes. The classification and proper searching of inventions are complicated and involved procedures, as they require the application of concise semantic values to often complex processes, machines, manufactures, compositions of matter, and their improvements. The searcher in this fictitious example might spend over a month studying the patents in the dozens of subclasses that might be pertinent to this particular set of improvements.

Having collected the pertinent patents, the searcher forwards them to the patent attorney for his further examination and study, after which the patent attorney decides that the radically different accelerating pump *item b* is patentable over the prior patented constructions and that the new improvement does not present any problem of infringement on the prior patent rights of others. Accordingly, the attorney prepares a patent application on *item b* for the inventor and files it in the United States Patent Office. The application is classified by the U. S. Patent Office under the subject matter of the invention as claimed in the application and then the application is sent to the particular examiner handling that subject matter.

Role of the Examiner

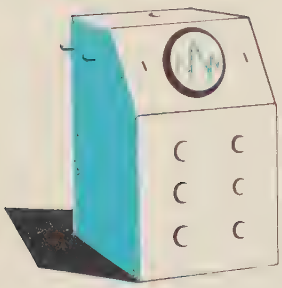
The examiner conducts his own search through what he feels are the pertinent subclasses and advises the patent attorney of his thinking regarding the patentability of the application. He does this by studying the prior patented constructions and related publications that he found in his search, and he either allows or rejects various claims in the new application on the basis of claims in these prior granted patents.

Correspondence ensues between the patent attorney and the examiner to ascertain exactly what, if anything, is patentable about *item b*. An agreement usually is reached in two or three years, whereupon the application either is issued as a patent (there is no disclosure by the U. S. Patent Office of the invention until the issuance of the patent) or the patent application is abandoned.

The patent attorney can present his arguments to the Patent Office Board of Appeals should he reach an impasse with the examiner. He also can appeal in the Federal Courts if he receives an adverse decision from the Patent Office Board of Appeals.

Solving the Problem of Infringement

With respect to the new linkage arrangement for the automatic choke *item c* the patent attorney decides that it infringes various claims of two unexpired patents X and Y. The earlier patent X shows a linkage similar to *item c* and the later patent Y shows the same linkage quite specifically. He also decides that *item c* is not patentable over patent Y. The searcher then is requested to conduct a *validity search* on the pertinent claims of patents X and Y. In the



validity search, the searcher investigates the prior patents more extensively than he did previously. For example, he may search the publications and the foreign-patent collections in the U. S. Patent Office Library, as well as the United States patents, to uncover a disclosure or disclosures to invalidate the claims of the patents **X** and **Y**. The searcher's goal is to find better prior disclosures for the patents **X** and **Y** than those found by the examiner in his search, called the *references of record*. On completion, the searcher forwards these new references to the patent attorney for examination and study.

The patent attorney decides that patent **X** is invalid, as it does not set forth invention over the new references. In some instances, the patent attorney may decide that a patent is invalid over a reference of record on the ground that the U. S. Patent Office erred in granting the patent.

The patent attorney decides that patent **Y** is valid. Next, the Division that originally submitted the improved carburetor design is advised that only *item c* of the improved carburetor presents any problem of infringement.

Many courses are open to the Division which originated the invention. For example:

(a) The present linkage of the automatic choke can be continued in use until the Division develops a different, improved linkage that does not infringe patent **Y**.

(b) Negotiations for seeking a license under, or the purchase of, patent **Y** can be initiated.

A possible aid to the Division in pursuing the first course is a prior-patent search. Such a search of previously granted patents is aimed at collecting expired or non-infringing patents having automatic-choke linkages that might be an improvement over the present linkage.

Assuming the willingness of the owner of patent **Y** to grant a license, the course that would be followed by the Division would be that which proved most advantageous from an economic standpoint. The Division concerned may feel that an improved linkage can be developed at a much lower cost than the cost of a license, and such an occurrence is often the case when the patent owner is not fully aware of the extent of his patent's coverage and, consequently, overvalues it. Inventors usually invent without full knowledge of the prior art in their field and, therefore, are inclined to believe that their patents are broader in scope than they actually are unless they become familiar with the references of record and the claims in their patents.

The patent literature many times discloses devices far in advance of the periods when the devices come into actual use and become familiar to the technician. An interesting example is afforded by French patent No. 412,478 which was issued in 1910 to Marconnet and disclosed the main elements that are common to all non-rocket thermal jet systems, namely, the air compressor, the combustion chamber, and the exhaust diffuser—far in advance of the turbo-jet engines of World War II.

On this and the following pages are listed some of the patents granted during the period from December 1, 1953 to January 31, 1954. The brief patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each patent.

Patents Granted

• **Howard K. Gandelot,** *General Motors Engineering Staff, GM Technical Center, Detroit, Michigan, for a Foot Dimmer Switch, No. 2,661,400, issued December 1.* This invention relates to a two-position foot dimmer switch wherein the headlights may be temporarily flashed to upper-beam position when the switch contacts are in the low-beam position and the plunger of the switch is rocked from its normal position.

Mr. Gandelot serves as engineer-in-charge of the Vehicle Safety Section, General Motors Engineering Staff. He has been with this Section since starting with General Motors in 1940. Mr. Gandelot earned the B. S. degree in mechanical engineering in 1917 from Carnegie Institute of Technology. This is the second patent granted as a result of his work. He has written several papers on engineering safety in automobiles. Mr. Gandelot is a member of A.S.M.E., S.A.E., Engineering Society of Detroit, and National Society of Professional Engineers. In addition, he is chairman of the Vehicle Safety Subcommittee of the Engineering Advisory Committee of the Automobile Manufacturers Association.

• **Raymond C. Davis and John T. Marvin,** *Inland Manufacturing Division, Dayton, Ohio, for a Method of Making Grommets, No. 2,660,759, issued December 1.* This patent relates to a method for manufacturing rubber grommets of free spiral shape that are used to protect cables passing through walls.

Mr. Davis' biography was published previously on page 55 of the September-October 1953 issue of the General Motors Engineering Journal.

Mr. Marvin's biography was published previously on page 56 of the September-October 1953 issue of the General Motors Engineering Journal.

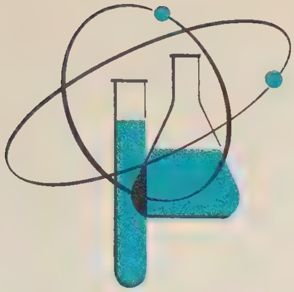
• **Robert T. Doughty,** *Cadillac Motor Car Division, Detroit, Michigan, for an Internal-Combustion Engine Ventilating System, No. 2,660,987, issued December 1.* This patent relates to an air-circulating fan on the distributor drive shaft within the opening therefor in the partition wall separating the engine crankcase from the valve chamber.

Mr. Doughty's biography was published previously on page 43 of the January-February 1954 issue of the General Motors Engineering Journal.

• **James E. Jones,** *Ternstedt Division, Detroit, Michigan, for a Switch, No. 2,661,407, issued December 1.* This invention relates to a door switch that normally closes a lighting circuit when the door is open and includes the additional feature whereby the switch will cause the circuit to be opened regardless of whether the door is open or closed.

Mr. Jones serves as production foreman of the Paint Finish Department at Ternstedt. He has been in production work relating to automobile-body hardware and parts at this Division for more than 20 years. He began as a racker in 1931 and four years later he was promoted to assistant foreman. In 1938 he was appointed to his present position. This is the first patent resulting from his work.

• **Clarence P. McClelland,** *Fisher Body*



Division, Detroit, Michigan, for a Windshield-Wiper Drive Apparatus, No. 2,660,894, issued December 1. This patent relates to an improved device for tensioning the flexible drive cables which extend between the wiper motor and each operating shaft upon which a wiper is mounted.

Mr. McClelland serves as senior project engineer in the Design and Drafting Engineering Department of Fisher Body. His initial General Motors employment was as a junior engineer with the Cadillac Motor Car Division in 1933. In 1941 he transferred to his present Division as a project engineer. This is the second patent granted as a result of his product-design work on windshield wipers and automotive instrument panels.

• **Thomas H. Mitzelfeld and Andrew W. Zmuda,** *Research Laboratories Division, GM Technical Center, Detroit, Michigan, and Buick Motor Division, Flint, Michigan, respectively, for a Valve-Rotating Device, No. 2,660,990, issued December 1.* This patent relates to various one-way rotary clutch arrangements on the upper end of the valve stem and actuated by the valve rocker arm for imparting progressive rotation to the valve during reciprocation.

Mr. Mitzelfeld serves as a research engineer in the Automotive Engines Department of the Research Laboratories. He was promoted to this position in 1951, three years after joining the Division as a junior engineer in this same Department. Mr. Mitzelfeld earned the B.S.M.E. degree from Michigan State College in 1947. His past work on valve-rotator development has resulted in one other granted patent. He is presently concerned with the testing of multi-cylinder engines. Mr. Mitzelfeld is a member of Tau Beta Pi, Phi Kappa Phi, and the Society of Automotive Engineers.

Mr. Zmuda is no longer with the Division.

• **Robert L. Needham,** *Delco Products Division, Dayton, Ohio, for a Motor Cradle, No. 2,661,172, issued December 1.* This invention relates to a cradle for an electric motor constructed of wire framing.

Mr. Needham serves as a design engineer at Delco Products. He started with the Division in 1941 as a junior engineer. In 1942 he transferred to the Strut Laboratory for a two-year period, leaving to serve in the Army for two years. He returned to Delco Products in 1946 in the Engineering Laboratories and transferred to Design Engineering in 1948. In his present capacity he is concerned with the mechanical phases of fractional-horsepower motor design. Ohio State University granted him the bachelor's degree in metallurgical engineering in 1941. He is a member of Tau Beta Pi.

• **Thomas C. Van Degrift,** *Research Laboratories Division, GM Technical Center, Detroit, Michigan, for Creep Testing of High-Temperature Alloys, No. 2,660,881, issued December 1.* This invention relates to an apparatus for testing metallic specimens by simultaneously applying tensile and vibratory stresses to the specimen at elevated temperatures.

Mr. Van Degrift's biography was published previously on page 52 of the January-February 1954 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

• **Floyd A. Wyczalek,** *Research Laboratories Division, GM Technical Center, Detroit, Michigan, for a Device for Determining Borderline Detonation, No. 2,660,883, issued December 1.* This invention relates to a temperature-responsive device to be threaded into an opening in the combustion chamber of an engine. The device comprises what amounts to two thermocouples in series opposed with the hot ends affected by the same temperature but having different surface areas exposed to the varying temperature of the burning charge.

Mr. Wyczalek has recently been promoted to supervisor of single-cylinder engines in the Automotive Engines Department of the Research Laboratories Division. Since joining the Laboratories in 1946 as junior engineer he has advanced through the positions of research engineer and senior engineer. He received the B.S.M.E. degree in 1946 from Worcester Polytechnic Institute. He served in the U.S. Navy from 1942 to 1946, separating with the rank of ensign. Previously, he had been employed by Buick Motor Division as a co-op student at General Motors Institute. He is a member of Tau Beta Pi, Sigma Xi, S.A.E., and A.S.M.E.

• **Marshall W. Baker,** *Frigidaire Division, Dayton, Ohio, for an Open-Top Display Refrigerating Apparatus, No. 2,661,604, issued December 8.* This patent is directed to a frozen-food display case in which the cold air flows upwardly through hollow separating walls and is distributed over the frozen food from the upper ends of the hollow walls.

Mr. Baker serves as manager of the Commercial and Air Conditioning Engineering Department of Frigidaire. He joined the Division in 1925 as a test engineer and was promoted through the positions of engineer-in-charge of the Test Department, senior project engineer on compressors, and staff head engineer on miscellaneous war products, to his present position. Mr. Baker earned the bachelor's degree in mechanical engineering from Ohio State University in 1925. He is co-author of a paper on automobile air conditioning. His technical affiliations include membership in the American Society of Refrigerating Engineers.

• **Max G. Bales,** *Delco-Remy Division, Anderson, Indiana, for an Ignition Distributor and Coil Unit, No. 2,662,105, issued December 8.* This patent deals with a distributor having a weatherproof casing that houses the ignition coil and condenser.

Max G. Bales, *Delco-Remy Division, Anderson, Indiana, for a Resistor Terminal, No. 2,662,151, issued December 8.* This patent is directed to a resistor and terminal assembly used in connection with the distributor housing, the terminal being in circuit with the ignition coil and the circuit breaker.

Mr. Bales' biography was published previously on page 52 of the September-October 1953 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

• **Hooper J. Houck and Richard M. Morgan,** *Moraine Products Division, Dayton, Ohio, for a Drilling and Tanging Machine, No. 2,661,523, issued December 8.* This invention relates to an improved automatic machine for drilling and forming a tang in a semicircular bearing element.

Mr. Houck serves as plants manager at Moraine Products. In 1923 he joined the Dayton Fan Company which later became a part of the General Motors Corporation.

These patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each one.

Starting in 1929 as foreman of the Tool Division, Mr. Houck served with the General Motors Radio Corporation for four years. Later he served for short periods with the Delco Products and the Delco Brake Divisions. In 1942 he transferred to Moraine Products, his present Division, and in 1951 he was promoted to plants manager. This is the first patent granted as a result of Mr. Houck's work with drilling and tanging machines.

Mr. Morgan is no longer with the Division.

• **Brooks H. Short,** *Delco-Remy Division, Anderson, Indiana, for an Ignition System, No. 2,662,202, issued December 8.* This invention relates to an ignition system wherein an auxiliary condenser charged between firing intervals is provided with a discharge path to the spark plug when the sparking voltage is induced in the secondary winding of an ignition coil so as to increase the heat and duration of the spark.

Mr. Short's biography was published previously on page 56 of the March-April 1954 issue of the General Motors Engineering Journal.

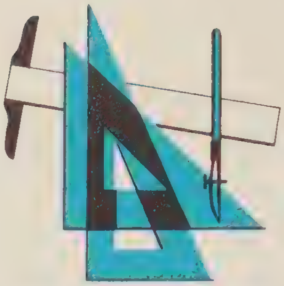
• **Clovis W. Lincoln and Errol A. Schroeder,** *Saginaw Steering Gear Division, Saginaw, Michigan, for a Transmission Control, No. 2,662,419, issued December 15.* This invention relates to the mounting of an automatic-transmission control lever upon a steering column in a manner such as will enable actuation of the transmission via a control sleeve concentric about the steering column and centrally disposed within a tubular steering-column housing.

Mr. Lincoln's biography was published previously on page 53 of the November-December 1953 issue of the General Motors Engineering Journal.

Mr. Schroeder is no longer with the Division.

• **George R. Long,** *Frigidaire Division, Dayton, Ohio, for a Method of Making Heat-Exchange Structures, No. 2,662,273, issued December 15.* This patent relates to a process of manufacturing a plate-type heat exchanger by forge welding two plates together after a pattern of stop-weld material has been applied to one sheet. Internal passages thus formed are then dilated while the plate is confined between two limiting surfaces.

Mr. Long is manager of Frigidaire's Materials and Process Engineering Department—a post he has held since 1937. He directs development work in metal-



lurgy, porcelain enamel, paints, refrigerants, oils, and plastics. His 25-year association with Frigidaire began as a co-op student from Antioch College. Later he was advanced to the positions of metallurgist and section head-in-charge of materials and processes at two Frigidaire plants. He holds the B.S. degree in chemistry from Antioch College (1927) and the B.S. degree in metallurgy from Massachusetts Institute of Technology (1929). He is a member of several technical societies and is a past-chairman of the Dayton Section, A.S.M. and a regional representative of the A.I.M.E.

• **Wheeler G. Lovell and Nelson E. Phillips,** *Research Laboratories Division, Detroit, Michigan, for an Apparatus for Separating Solid Metallic Particles from an Electrolyte and Compacting the Same, No. 2,662,643, issued December 15.* This invention relates to an apparatus for separating solid metallic particles from an electrolyte and compacting the metal particles into a coherent spongy mass.

Mr. Lovell is no longer with the Division.

Mr. Phillips serves as supervisor of exhibits in the Administrative Engineering Department of the Research Laboratories. Directly after earning the B.S.Ch.E. degree from University of Dayton in 1928, Mr. Phillips joined Research Laboratories as a research chemist in the General Chemistry Department. During World War II he was supervisor of production at a temporary plant set up to experiment with triptane—a special aircraft fuel. This is the third patent granted on the basis of Mr. Phillips' work with electrolytic processes. Mr. Phillips is a member of the American Chemical Society.

• **Bertram A. Schwarz,** *Delco Radio Division, Kokomo, Indiana, for a Combination Radio Receiver, No. 2,662,975, issued December 15.* This invention relates to a combination automobile and portable household receiver which may be unlocked and removed from a dash compartment of a vehicle, where it is used as an automobile receiver, and then used with a separate self-contained speaker and a line-operated power supply as a household receiver.

Mr. Schwarz serves as chief engineer of the Engineering Department at Delco Radio. He has been with the Division in this capacity since 1936 when it was established to produce automotive radio sets. Currently, Mr. Schwarz is concerned with transistor development and use and with radio miniaturization. This patent is the twenty-third granted as a result of his past work on radio components. Mr. Schwarz is a member of the Acoustical Society of America. In addition, he is a member of the Institute of Radio Engineers and belongs to its Professional Group—Broadcast and TV Receivers. Other technical affiliations include vice-chairmanship of the Vehicular Committee—Engineering Department of the Radio-Electronics-Television Manufacturers Association and membership on the Association's Receiver Executive Committee.

• **Arthur J. Anderson, Hubert L. Driffill, and Marshall E. Lentz,** *Fabricast Division, Bedford, Indiana, for a Core Lifting-and-Setting Fixture, No. 2,663,058, issued December 22.* This invention relates to an apparatus for picking up a series of articles, such as a plurality of cores, arranged in a circle whereby the entire series may be moved as a unit and located in a mold.

Mr. Anderson serves as a project engineer in the Process Engineering Department at Fabricast. His initial General Motors employment was in 1940 with Delco-Remy Division as a plater helper. He transferred to Fabricast in 1945 as an inspector and since then has been promoted through the positions of foreman, junior process engineer, and engineer—research and experimental—to his present position. This is the first patent granted as a result of his work with core lifting-and-setting fixtures.

Before his death in 1949, Mr. Driffill was chief foundry engineer at Fabricast. Employed in 1926 as a horn tester by Delco-Remy Division, Mr. Driffill transferred to Fabricast in 1945 as a project engineer. He was promoted to chief foundry engineer in 1947. He earned the B.S. degree in electrical engineering in 1929 from Purdue University.

Mr. Lentz is no longer with the Division.

• **Anton F. Erickson,** *Moraine Products Division, Dayton, Ohio, for a Check Valve for Master Cylinder, No. 2,663,540, issued December 22.* This patent relates to an improved master-cylinder check valve which has a retainer to positively position the rubber outlet valve within the valve cup. This retainer has projections as an added protection against possible blocking of the brake-fluid conduit.

Mr. Erickson's biography was published previously on page 46 of the March-April 1954 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

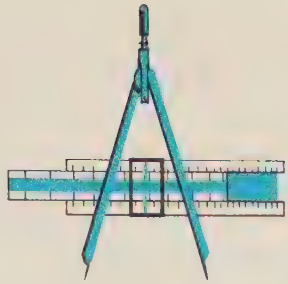
• **David A. Galonska, Godfrey G. Kearful, and Clovis W. Lincoln,** *Saginaw Steering Gear Division, Saginaw, Michigan, for a Jack, No. 2,663,542, issued December 22.* This patent relates to an improved ball-nut bumper jack in which the slot for the lifting hook in the upright column has been located on the opposite side of the column with relation to the bumper-engaging portion of the lifting hook to increase the load-carrying capacity of the column.

Mr. Galonska serves as project engineer at Saginaw Steering Gear. In this capacity, he is concerned with all applications of ball-bearing and screw and nut assemblies. Mr. Galonska started with Saginaw Steering Gear in 1940 as a tool designer and transferred to the Product Engineering Department in 1943 as a designer. He also served for three years as experimental engineer-in-charge of the Physical Test Laboratory and Model Shop before appointment to his present position in 1952. Many of his projects were concerned with the design and development of jacks, splines, gearshift mechanisms, and bi-directional brake devices.

Mr. Kearful's biography was published previously on page 44 of the March-April 1954 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

Mr. Lincoln's biography was published previously on page 53 of the November-December 1953 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

• **Arthur J. Schutt,** *Harrison Radiator Division, Lockport, New York, for a Temperature-Control Valve, No. 2,663,499, issued December 22.* This patent relates to a thermostatically operable valve for controlling the flow of heating fluid from the engine to the core of a car heater. The thermostat is adjustable to different positions to control the temperature within the vehicle.



Mr. Schutt serves as assistant chief engineer in the Engineering Department at Harrison Radiator. Employed as an engine designer in the Product Study Department, Central Office Engineering Staff in 1929, he transferred to Harrison Radiator Division in 1931 as an experimental engineer. He was promoted to his present position in 1936, in which capacity he is in charge of the Research Section of his Department. This is the sixth patent granted as a result of Mr. Schutt's work in the fields of heat transfer and temperature controls. Mr. Schutt is a member of the S.A.E.

• **Frank Westcott,** *Vauxhall Motors, Limited, Luton, England, for a Closure-Cap Device for Receptacles, No. 2,663,447, issued December 22.* This patent relates to a door that is flush with the rear fender and that carries a resilient disc to seal the end of the gasoline-filler spout.

Mr. Westcott serves as assistant passenger-vehicle engineer at Vauxhall Motors, Ltd. He started as a draftsman in the Design Office at Vauxhall Motors in 1919. He was promoted to his present position in 1950. Mr. Westcott figured prominently in the development of the "E" series passenger cars. His work with steering and suspension-system problems has resulted in two previously granted United States patents. He is a member of the Automobile Division of the Institution of Mechanical Engineers.

• **Carel F. Abresch,** *Frigidaire Division, Dayton, Ohio, for a Domestic Appliance, No. 2,664,050, issued December 29.* This patent pertains to a rotary-vane water pump having, as its impeller, a flexible rubber hub with integral semicylindrical beads between the spaced, integral, flexible radial vanes.

• **Carel F. Abresch,** *Frigidaire Division, Dayton, Ohio, for a Squeezer Extractor, No. 2,666,315, issued January 19.* This patent pertains to a clothes washer having a lid-mounted flexible diaphragm that wrings the clothes when a vacuum is applied to the tub.

Mr. Abresch's biography was published previously on page 52 of the September-October 1953 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

• **Bernard A. Brown and Leonard A. Erickson,** *Moraine Products Division, Dayton, Ohio, for a Machine for Operating on Briquettes, No. 2,664,018, issued December 29.* This patent relates to a briquetting machine for making metal-powder compacts wherein the delivery chute is provided with clamping means for holding the compacts in predetermined positions so that machine operations can be carried out thereon.

Mr. Brown serves as general manager of Moraine Products. In 1913 he started with Delco in Dayton, Ohio, as an assembler, was promoted to assistant chief inspector in 1920, to chief inspector in 1926, and to factory manager in 1936. In 1940 Mr. Brown was appointed general manager of Delco Brake Division. Two years later, when Delco Brake merged with Moraine Products Division, he was appointed general manager of the new Division. Mr. Brown attended Antioch College in Ohio. His technical affiliations include membership in the Dayton Foreman's Club, Engineer's Club, and Army Ordnance Association.

Mr. Erickson is no longer with the Division.

• **Morris V. Dadd and Paul L. Vermaire,** *Diesel Equipment Division, Grand Rapids, Michigan, for an Exhaust-Valve Rotator, No. 2,664,076, issued December 29.* This patent relates to the use of a coil spring as a one-way rotary clutch to effect progressive valve rotation, wherein the clutch spring alternately grips and releases the valve as it is cammed in alternately opposite directions about the stem by a pin inclined to the stem axis and rigid with the engine.

Mr. Dadd serves as a junior engineer in the Engineering Department of Diesel Equipment. He attended General Motors Institute under the sponsorship of this Division and earned the B.M.E. degree from the Institute in 1951. This is the first granted patent resulting from his work with valve-rotator development. Mr. Dadd served in the Air Force as an aerial navigator from December 1943 to January 1946 and from August 1951 to August 1952, separating with the rank of first lieutenant. His military citations include the Distinguished Flying Cross and the Air Medal with two Oak Leaf Clusters.

Mr. Vermaire's biography appears in the Contributors' Section of this issue of the GENERAL MOTORS ENGINEERING JOURNAL.

• **Harold V. Elliott,** *Delco-Remy Division, Anderson, Indiana, for a Circuit Breaker, No. 2,664,480, issued December 29.* This patent relates to a thermostatically controlled circuit breaker that is adapted to break the circuit when an overload occurs and that may be reset through a latch.

Mr. Elliott's biography was published previously on page 46 of the March-April 1954 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

• **John P. Hobart,** *Chevrolet Motor Division, Central Office, Detroit, Michigan, for a Shift-Rod Adjusting Clamp, No. 2,664,305, issued December 29.* This improved rod clamp employs an apertured block suitably cut for the rod and an axially aligned pivot pin and clamping stud to be located at right angles to the aperture for the rod. A hollow clamping member fits over the stud and block and is secured by a nut to positively and quickly lock the rod in the block.

Mr. Hobart serves as a project engineer with Chevrolet Motor. He started with Chevrolet as a designer in 1939. Previously, he had been a designer at Oldsmobile Division from 1929 to 1932 and he had automotive experience with several other firms. University of Cincinnati granted Mr. Hobart the electrical engineering degree in 1921. He has worked on the Powerglide and Hydra-Matic automatic transmissions and, currently, is concerned with development work on special transmissions and transmission controls. This is the first patent granted on the basis of Mr. Hobart's work with automotive components. He is a member of the Society of Automotive Engineers.

• **Stanley R. Prance and Harry O. Waag,** *Inland Manufacturing Division, Dayton, Ohio, for a Method of Decorating Plastics, No. 2,663,911, issued December 29.* This patent relates to a method for decorating plastics, for example, the hand-grip portions of steering wheels are textured to simulate a leather grain by softening the plastic and impressing the texture therein.

These patent descriptions are informative only and are not intended to define the coverage which is determined by the claims of each one.

Mr. Prance's biography was published previously on page 34 of the June-July 1953 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

Mr. Waag serves as head of the Paint Laboratory, Inland Manufacturing. He started with this Division in 1925 in the Paint Department and was promoted to head of the Paint Laboratory in 1933. At present, the Laboratory is concerned with perfecting the application of flexible, decorative coatings to rubber for use as automotive-windshield and window strips. His earlier laboratory work on the development of colored lacquers for decorative metal evaporated multicolored plastic emblems has resulted in two previously granted patents. Mr. Waag is a member of the Southern Ohio Rubber Group and the General Motors Paint Committee.

• **Herman L. Hartzell and Argyle G. Lautzenhiser,** *Delco-Remy Division, Anderson, Indiana, for an Engine Governor, No. 2,664,867, issued January 5.* This patent relates to an engine-speed control device which features a centrifugally actuated slide valve rotated by the engine-distributor shaft and variably controlling the pressure applied to a pressure-responsive device which adjusts the position of the engine-throttle valve to govern the speed of the engine.

• **Argyle G. Lautzenhiser,** *Delco-Remy Division, Anderson, Indiana, for an Engine Governor, No. 2,664,868, issued January 5.* A modification of the preceding patent, using engine lubricating-oil pressure instead of manifold pressure as a source of controllable power applied to the pressure-responsive device through the governor valve.

• **Argyle G. Lautzenhiser,** *Delco-Remy Division, Anderson, Indiana, for an Engine Governor, No. 2,664,906, issued January 5.* An improvement of the two preceding patents.

Mr. Hartzell's biography was published previously on page 63 of the June-July 1953 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

Mr. Lautzenhiser's biography was published previously on page 54 of the September-October 1953 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

• **Elbridge F. Bacon,** *AC Spark Plug Division, Flint, Michigan, for a Pressure Gage, No. 2,664,584, issued January 12.* This invention calibrates Bourdon gages and has a linked arm on a pivoted U-frame extending through the frame base between its legs made bendable to move the link pivot relative to the pointer-frame pivots.

Mr. Bacon's biography was published previously on page 56 of the November-December 1953 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

• **William E. Brill,** *Cleveland Diesel Engine Division, Cleveland, Ohio, for a Crankshaft Thrust Bearing Oil Seal, No. 2,665,955, issued January 12.* This patent is directed to a split metal ring and oil slinger arrangement for sealing against the escape of oil along an engine crankshaft.

Mr. Brill's biography was published previously on page 34 of the June-July 1953 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

• **Roland P. Koehring,** *Moraine Products Division, Dayton, Ohio, for a Method of Impregnation, No. 2,665,599, issued January 12.* This patent is concerned with a method of impregnating porous, ferrous parts with a cuprous material wherein the porous, ferrous part may be infiltrated to a desired degree with the cuprous material without being pitted or dissolved by the infiltrating metal.

Mr. Koehring serves as chief metallurgist at Moraine Products. He started with General Motors in 1920 as a laboratory assistant in the Metallurgical Research Laboratory of the GM Research Corporation (now called the Research Laboratories Division). He transferred to Moraine Products as a metallurgist in 1925 and was promoted to chief metallurgist in 1942. Mr. Koehring's work in the field of powder metallurgy has resulted in 34 granted patents. He is a member of a number of technical societies. In addition, he serves as chairman of the Subcommittee III on Metal Powder Products of the A.S.T.M. and chairman of the Technical Subcommittee of the Powder Metallurgy Committee, American Ordnance Association.

• **Robert C. Woofter,** *Packard Electric Division, Warren, Ohio, for a Spark-Plug Boot, No. 2,665,673, issued January 12.* This patent relates to a protective spark-plug boot which can be employed with plugs where the secondary conductor associated therewith is in alignment with the plug, or at an angle of 90° to its axis.

Mr. Woofter serves as a product development engineer at Packard Electric. He joined the Division in 1940 and his early

experience was in the Process Engineering Department. In 1949 he transferred to the Product Development Section where he did design work on ignition conduits, lamp sockets, switches, and connectors. Currently, he is concerned with the design of multiple connections for automotive harnesses, such as the one used on the 1954 Oldsmobile. Mr. Woofter attended Fenn College in Cleveland. He is a member of the American Society of Tool Engineers.

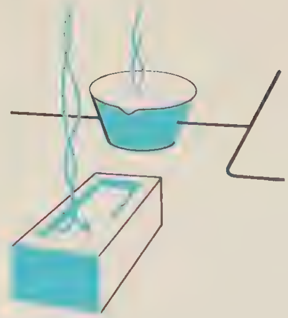
• **Robert R. Candor,** *Frigidaire Division, Dayton, Ohio, for a Squeezer Extractor Washing Machine, No. 2,666,316, issued January 19.* This patent is directed to a vacuum-type washing machine with a tub oscillating around a vertical axis and provided with a flexible-diaphragm cover which wrings the clothes when a vacuum is applied to the tub.

Mr. Candor's biography was published previously on page 54 of the November-December 1953 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

• **John H. Heidorn,** *Frigidaire Division, Dayton, Ohio, for an Apparatus for Magnetically Locating a Rotor with Respect to the Stator, No. 2,666,892, issued January 19.* This invention employs a special test rotor having four equally spaced electromagnetic poles to properly center a rotor within the stator of an electric motor. The test rotor is mounted in the rotor bearings of the stator. An electrodynamometer instrument measures the differences in the electromagnetic relationships between the opposite poles and bearings are adjusted until the differences are eliminated.

Mr. Heidorn serves as a section engineer at Frigidaire. He joined the Division in 1938 as a stock tracer and was enrolled during the same year as a cooperative engineering student at General Motors Institute. He was promoted to layout in 1945, to project engineer in 1948, to senior engineer in 1950, and to his present position, section engineer, in 1953. His major projects have been concerned with compressor development and his work has resulted in one patent in this field.

• **Robert W. Guernsey and Ray C. Ulrey,** *Detroit Diesel Engine Division, Detroit, Michigan, for a Torsional Vibration Isolating Coupling, No. 2,667,049, issued January 26.* This invention involves a centrifugally actuated, frictional, torsional-vibration-



absorbing coupling which allows relative movement between the coupled elements for low phase-angle differences but increasingly resists relative movement as the phase angle increases.

Mr. Guernsey's biography was published previously on page 42 of the January-February 1954 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

Mr. Ulrey's biography was published previously on page 42 of the January-February 1954 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

• **Howard C. Mead and George W. Onksen, Jr.,** *Guide Lamp Division, Anderson, Indiana, for a Tail-Lamp Lens, No. 2,667,572, issued January 26.* The invention relates to a lens, the exterior surface of which follows a peculiar surface contour and the interior surface of which is modified by continuously curved light collimating and connecting surfaces arranged to properly direct the light through the exterior surface.

Mr. Mead serves as assistant chief engineer in the Engineering Department at Guide Lamp. His work in automotive lighting began with the Guide Motor Lamp Manufacturing Company, Cleveland, Ohio, which he joined in 1919 after attending Western Reserve University. (In 1928 this Company became the Guide Lamp Division of General Motors.) His work has resulted in 24 granted patents with many others in this field still pending. He is chairman of the Lamp Subcommittee of the Society of Automotive Engineers and serves as a member of the S.A.E. Lighting Committee, the National Committee on Uniform Traffic Laws and Ordinances, and the Engineering Standards Committee of General Motors.

Mr. Onksen's biography was published previously on page 64 of the September-October 1953 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

• **Robert C. Moser and William J. Purchas, Jr.,** *Diesel Equipment Division, Grand Rapids, Michigan, for a Hydraulic Lash Adjuster, No. 2,667,149, issued January 26.* This patent covers certain improvements over the lash adjuster of patent No. 2,665,669, particularly with respect to a relocation of the check valve limiting cage-wear surface for reduced manufacturing cost and a more rugged design.

Mr. Moser is no longer with the Division.

Mr. Purchas' biography was published previously on page 42 of the January-February 1954 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

• **Milton M. Paluch and Conrad A. Teichert,** *Diesel Equipment Division, Grand Rapids, Michigan, for an Automatic Gas-Inlet Valve, No. 2,667,155, issued January 26.* This patent relates to a valve sensitive to change in combustion-chamber pressure and acting in response to engine fuel-supply pressure for automatically timing the admission and cut-off of fuel to the engine cylinder.

Mr. Paluch has served as project engineer in the Engineering Department of Diesel Equipment since 1947. He has worked on the development of a compression-operated Diesel injector, a hydraulic gas valve, and an automatic gas-inlet valve—the latter resulting in a granted patent. Mr. Paluch earned the B.S. degree in 1937 from Central College of Chicago and did graduate study at University of Chicago and the University of Notre Dame, South Bend, Indiana. He is a member of Tau Sigma Tau.

Mr. Teichert serves as senior designer in the Product Engineering Department of Diesel Equipment. He started with General Motors in 1943 as general supervisor of the Production Engineering Department in Fisher Body Division's Grand Rapids plant. In 1946 he transferred to his present Division as senior designer, in which capacity he is concerned with the design of fuel-injection devices and related controls. Mr. Teichert earned a degree in mechanical engineering in 1922 from Mittweida Technical College and in 1933 earned an aeronautical engineering degree from University of Berlin—both in Germany. He is a member of the S.A.E.

Solution to the Problem: Plot the Ground Plans of Visibility from the Driver's Position in an Automobile

By REO S. BRINK*
GM Proving Ground
Milford,
Michigan

Unusual shapes give positive information to motor-car designers

The curious pattern of a ground plan of driver visibility sets forth information of a precise nature which is available to engineers and stylists for comparison and evaluation of various car models and for planning future designs. Test engineers at the General Motors Proving Ground, Milford, Michigan, obtain data for such a pattern in a special laboratory setup. These data then may be plotted with the application of trigonometry and geometry. This is the solution to the problem presented in the March-April 1954 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

THE solution to the problem depends upon taking the tabulated points obtained from the vertical grid-work screens, positioned in front and back of the test car, computing the projections of these points, and plotting the forward- and rearward-visibility ground plans. The solution procedure depends on a knowledge of basic geometry and trigonometry.

Determination of Driver Forward Visibility

The pattern formed on the semicircular grid-work screen positioned in front of the test car represents the extent of the driver's unobstructed forward visibility. The dark portions of the pattern indicate obstructions in the driver's view and the clear portions of the pattern indicate unobstructed vision. The points read from the grid-work screen are those which are on the edge of the driver's clear view. Each point read and tabulated denotes the number of degrees to the right or left of the mid-point position between the driver's eyes and also the vertical distance above the ground. To determine the driver's forward visibility it is necessary to calculate the polar coordinates of each tabulated point on the edge of the driver's vision.

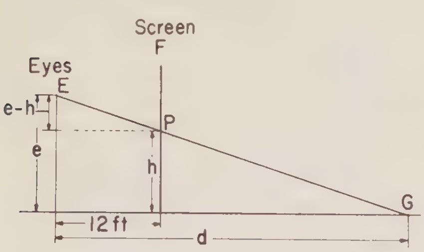


Fig. 1—Diagram drawn in a vertical plane through the mid-point between the eyes E and a point P on the boundary for forward vision read from screen F for the purpose of finding the distance d to the point G at which the projected line of vision touches the ground.

In Fig. 1, which is a diagram drawn in a vertical plane through the mid-point between the two six-volt light bulbs used to simulate the eye positions of the driver, the dimensions necessary to complete the first step in determining driver forward visibility are given. The semicircular screen F is located at a radius of 12 ft from E, which is the mid-point position between the driver's eyes. The height of this mid-point position above the ground is given by dimension e and is a constant value of 4.48 ft. The point P represents the position of one of the points on the edge of driver visibility formed by the light-bulb pattern on screen F; h is the height of this point of vision from the ground. The point at which the line of vision meets the ground is denoted by G.

It is necessary first to determine the dimension d, which is the horizontal distance from the eye point to the point at which the line of vision meets the ground. Referring to Fig. 1 and using similar triangles:

$$d/12 = e/(e-h)$$

therefore,

$$d = 12\, e/(e-h).$$

The first point which was tabulated from the edge of driver vision on screen F was at $-39.4°$ to the left of E and at a height h of 4.29 ft. The negative angle indicates the angle is read to the left of the mid-point position E. Substituting the known values for h and e in the expression for d gives:

$$d = 12 \times 4.48/(4.48 - 4.29) = 282.9 \text{ ft}.$$

The polar coordinates of point d, therefore, are 39.4° to the left of a line straight ahead of the driver and 282.9 ft away.

To complete the exact location of the first tabulated point it is necessary to know its distance ahead of and to the left of the driver. Fig. 2 shows a plan view of the semicircular screen F, the mid-point position E, and the line of vision to the point on the ground at G. The length d has been solved and the angle α is the angle read from the screen pattern and is equal to $-39.4°$. Referring to Fig. 2, the Cartesian coordinates necessary to locate point G are found by the following relationships:

$$\sin \alpha = x/d$$
$$x = d \sin \alpha$$

and

$$\cos \alpha = y/d$$
$$y = d \cos \alpha.$$

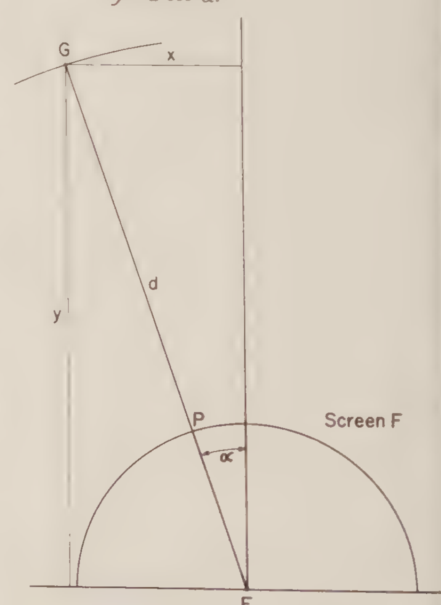


Fig. 2—Diagram drawn as a plan view for the determination of the rectangular coordinates of the point G at which the line of vision touches the ground.

*For Mr. Brink's biography and photograph, please see p. 61 of the November-December 1953 GENERAL MOTORS ENGINEERING JOURNAL. This is the second problem and solution contributed by Mr. Brink, supervisor of the engineering test data activity of the Engineering Test Department, GM Proving Ground, Milford, Michigan.

Angle (degrees) α −left +right	Screen Height (feet) h	Eye Height minus Screen Height (feet) e−h	Distance to Point on Ground (feet) $d=\frac{12e}{e-h}$	Functions of angle cos α	sin α	Rectangular Coordinates of Point on Ground y axis d cos α	x axis d sin α
LEFT VENTIPANE DIVIDER STRIP							
39.4	4.29	0.19	282.9	0.7727	−0.6347	218.6	−179.6
39.3	4.25	0.23	233.7	0.7738	−0.6334	180.8	−148.0
39.3	4.29	0.19	282.9	0.7738	−0.6334	218.9	−179.2
LEFT VENTIPANE							
33.7	4.36	0.12	448.0	0.8320	−0.5548	372.7	−248.6
33.6	4.29	0.19	282.9	0.8329	−0.5534	235.4	−156.4
33.5	4.21	0.27	199.1	0.8339	−0.5519	166.0	−109.9
33.8	3.94	0.54	99.6	0.8406	−0.5417	83.7	−54.0
31.2	3.15	1.33	40.4	0.8554	−0.5180	34.6	−29.0
31.7	3.00	1.48	36.3	0.8508	−0.5255	30.8	−19.1
31.7	2.92	1.56	34.5	0.8508	−0.5255	29.4	−18.1
31.0	2.92	1.56	34.5	0.8572	−0.5150	29.6	−17.8
30.0	2.25	2.23	24.1	0.8660	−0.5000	20.9	−12.1
29.0	1.60	2.88	18.7	0.8746	−0.4848	16.4	−9.1
28.6	1.15	3.33	16.1	0.8780	−0.4787	14.1	−7.7
29.2	0.60	3.88	13.9	0.8729	−0.4879	12.1	−6.8
31.8	0.00	4.48	12.0	0.8499	−0.5270	10.2	−6.3
WINDSHIELD							
29.3	4.36	0.12	448.0	0.8721	−0.4894	390.7	−219.3
29.2	4.34	0.14	384.0	0.8729	−0.4879	335.2	−186.7
29.1	4.21	0.27	199.1	0.8738	−0.4863	173.9	−96.8
28.0	3.40	1.08	49.8	0.8829	−0.4695	44.0	−23.4
26.0	2.00	2.48	21.7	0.8988	−0.4384	19.5	−9.5
25.0	1.40	3.08	17.5	0.9063	−0.4226	15.9	−7.4
23.0	1.30	3.18	16.9	0.9205	−0.3907	15.6	−6.6
21.8	1.38	3.10	17.3	0.9285	−0.3714	16.1	−6.4
21.0	1.25	3.23	16.6	0.9336	−0.3584	15.5	−5.9
20.0	1.37	3.11	17.3	0.9397	−0.3420	16.3	−5.9
17.0	1.80	2.68	20.1	0.9563	−0.2924	19.2	−5.9
14.0	2.21	2.27	23.7	0.9703	−0.2419	23.0	−5.7
10.0	2.53	1.95	27.6	0.9848	−0.1736	27.2	−4.8
8.0	2.50	1.98	27.2	0.9903	−0.13917	26.9	−3.8
6.7	2.30	2.18	24.7	0.9932	−0.11667	24.5	−2.9
0.0	2.82	1.66	32.4	1.0000	0.0000	32.4	0.0
5.0	3.08	1.40	38.4	0.9962	0.08716	38.3	3.3
8.7	3.18	1.30	41.4	0.9885	0.15126	40.9	6.3

Angle (degrees) α −left +right	Screen Height (feet) h	Eye Height minus Screen Height (feet) e−h	Distance to Point on Ground (feet) $d=\frac{12e}{e-h}$	Functions of angle cos α	sin α	Rectangular Coordinates of Point on Ground y axis d cos α	x axis d sin α
WINDSHIELD (Cont'd)							
+ 8.5	3.33	1.15	46.7	0.9890	0.14781	46.2	6.9
+ 9.1	3.41	1.07	50.2	0.9874	0.15816	49.6	7.9
+10.7	3.13	1.35	39.8	0.9826	0.1857	39.1	7.4
+12.0	3.13	1.35	39.8	0.9781	0.2079	38.9	8.3
+13.7	3.20	1.28	42.0	0.9715	0.2368	40.8	9.9
+15.0	3.10	1.38	39.0	0.9657	0.2588	37.7	10.1
+20.0	3.00	1.48	36.3	0.9379	0.3420	34.1	12.4
+26.0	2.82	1.66	32.4	0.8988	0.4384	29.1	14.2
+31.5	2.67	1.81	29.7	0.8526	0.5225	25.3	15.5
+40.0	2.63	1.85	29.1	0.7660	0.6428	22.3	18.7
+50.0	2.58	1.90	28.3	0.6428	0.7660	18.2	21.7
+53.8	2.43	2.05	26.2	0.5906	0.8070	15.5	21.1
+55.0	2.68	1.80	29.9	0.5763	0.8192	17.2	24.5
+57.0	3.02	1.46	36.8	0.5446	0.8387	20.0	30.9
+59.0	3.60	0.88	61.1	0.5150	0.8572	31.5	52.4
+60.5	4.02	0.46	116.9	0.4924	0.8704	57.6	101.7
+61.0	4.21	0.27	199.1	0.4848	0.8746	96.5	174.1
+61.1	4.29	0.19	282.9	0.4833	0.8755	136.7	247.7
+61.2	4.35	0.13	413.5	0.4818	0.8763	199.2	362.4
RIGHT VENTIPANE							
+66.5	4.35	0.13	413.5	0.3987	0.9171	164.9	379.2
+66.3	4.32	0.16	358.4	0.4019	0.9157	144.0	328.2
+66.2	4.29	0.19	282.9	0.4035	0.9150	114.2	258.9
+65.9	4.21	0.27	199.1	0.4083	0.9128	81.3	181.7
+65.0	3.98	0.50	107.5	0.4226	0.9063	45.4	97.4
+63.0	3.40	1.08	49.8	0.4540	0.8910	22.6	44.4
+62.0	3.00	1.48	36.3	0.4695	0.8829	17.0	32.0
+61.3	2.60	1.88	28.6	0.4802	0.8771	13.7	25.1
+62.0	2.27	2.21	24.3	0.4695	0.8829	11.4	21.5
+63.0	2.22	2.26	23.8	0.4540	0.8910	10.8	21.2
+67.0	2.20	2.28	23.6	0.3907	0.9205	9.2	21.7
+71.5	2.13	2.35	22.9	0.3173	0.9483	7.3	21.7
+71.5	2.21	2.27	23.7	0.3173	0.9483	7.5	22.5
+72.2	2.20	2.28	23.6	0.3057	0.9521	7.2	22.5
+71.9	4.20	0.28	192.0	0.3107	0.9505	59.7	182.5
RIGHT WINDOW							
+72.2	4.20	0.28	192.0	0.3057	0.9521	58.7	182.8
+72.8	1.92	2.56	21.0	0.2957	0.9553	6.2	20.1
+80.0	1.86	2.62	20.5	0.1736	0.9848	3.6	20.2
+90.0	1.80	2.68	20.1	0.0000	1.0000	0.0	20.1

Table I—Calculation of coordinates of points at which lines of forward vision projected through screen *F* meet the ground.

Substituting the calculated value of *d* and the known value of α into the above relationships establishes the values of *x* and *y* as follows:

$x = 282.9\ (\sin -39.4°) = -179.6$ ft to the left of the driver

$y = 282.9\ (\cos -39.4°) = 218.6$ ft ahead of the driver.

The exact location of the first tabulated point on the edge of vision is established. The same procedure is followed to establish the exact location of the other tabulated points. Table I is a summary of points needed to plot the ground plan. When all points have been plotted and properly connected, the ground plan of the driver's forward visibility is established.

Fig. 3 shows the completed ground plan for driver forward visibility. The shaded areas on the ground plan represent areas which are obstructed in the driver's view and cannot be seen by either eye.

Determination of Driver Rearward Visibility

The procedure necessary to determine driver rearward visibility is similar to that used for determining driver forward

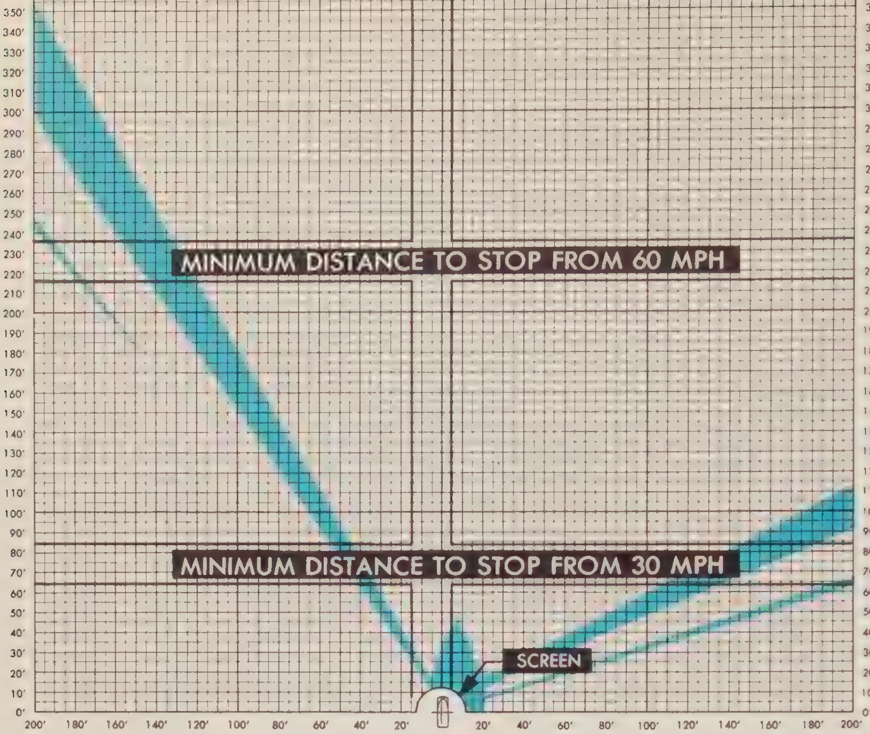


Fig. 3—Completed chart—Ground Plan of Driver's Vision—Forward.

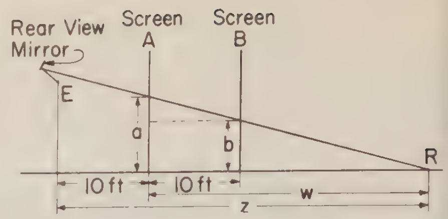


Fig. 4—Side elevation drawn in a vertical plane parallel to the car axis for the determination of the longitudinal distance *z* to the point *R* at which a reflected line of vision projected through screens *A* and *B* touches the ground.

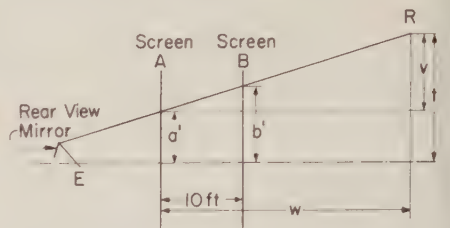


Fig. 5—Diagram drawn as a plan view of vision to the rear for the determination of the lateral distance *t* from the mid-point between the eyes to the point *R* at which a line of vision touches the ground.

visibility except that two plane screens are used instead of one semicircular screen. Two screens are used to avoid the complexities caused by the oblique angles of the rear-view mirror and related lines of vision and to include the effects of distortion caused by the rear-window glass.

The ground plan for driver rearward visibility is developed from the corresponding points read from screens *A* and *B*. Fig. 4 shows a diagram drawn in a vertical plane parallel to the test-car axis and passing through the mid-point between the eyes. Screen *A* is located 10 ft from the eye mid-point *E* and screen *B* is located 10 ft behind screen *A*. *R* represents the point at which the reflected line of vision projected through screens *A* and *B* touches the ground. The dimensions *a* and *b* represent the heights above the ground to the points on the screens through which the line of vision passes.

It is necessary first to determine the distance *z* which is the longitudinal distance from the eye mid-point *E* to the point *R* on the ground, through which the point of vision is projected. Referring

VISIBILITY TO THE REAR

No.	Screen A Vertical a	Screen B Vertical b	(a−b)	$w=\frac{10a}{a-b}$	Screen B Horizontal b′	Screen A Horizontal a′	(b′−a′)	$v=\frac{w(b'-a')}{10}$	z= w+10	t= v+a′
1	3.59	2.86	0.73	49.18	+0.83	0.00	+0.83	+ 4.08	59.2	+ 4.1
2	3.60	2.89	0.71	50.70	+2.40	+0.90	+1.50	+ 7.61	60.7	+ 8.5
3	3.70	3.08	0.62	59.68	+2.69	+1.08	+1.61	+ 9.61	69.7	+ 10.7
4	3.90	3.40	0.50	78.00	+2.80	+1.13	+1.67	+ 13.03	88.0	+ 14.2
5	4.10	3.73	0.37	110.81	+2.80	+1.13	+1.67	+ 18.51	120.8	+ 19.6
6	4.30	4.10	0.20	215.00	+2.78	+1.12	+1.66	+ 35.69	225.0	+ 36.8
7	4.46	4.36	0.10	446.00	+2.64	+1.05	+1.59	+ 70.91	456.0	+ 72.0
8	4.55	4.51	0.04	1137.50	+2.48	+0.90	+1.58	+179.73	1147.5	+180.6
9	4.56	4.51	0.05	912.00	+0.85	0.00	+0.85	+ 77.52	922.0	+ 77.5
10	4.55	4.51	0.04	1137.50	−0.85	−1.00	+0.15	+ 17.06	1147.5	+ 16.1
11	4.55	4.51	0.04	1137.50	−2.56	−2.00	−0.56	+ 63.70	1147.5	− 65.7
12	4.55	4.50	0.05	910.00	−4.36	−3.00	−1.36	+123.76	920.0	−126.8
13	4.54	4.49	0.05	908.00	−5.03	−3.40	−1.63	+148.00	918.0	−151.4
14	4.45	4.34	0.11	404.55	−5.30	−3.56	−1.74	− 70.39	414.6	− 74.0
15	4.30	4.10	0.20	215.00	−5.40	−3.62	−1.78	− 38.27	225.0	− 41.9
16	4.10	3.74	0.36	113.89	−5.42	−3.63	−1.79	− 20.39	123.9	− 24.0
17	3.90	3.40	0.50	78.00	−5.42	−3.62	−1.80	− 14.04	88.0	− 17.7
18	3.78	3.19	0.59	64.07	−5.38	−3.60	−1.78	− 11.40	74.1	− 15.0
19	3.66	3.00	0.66	55.45	−5.04	−3.40	−1.64	− 9.09	65.5	− 12.5
20	3.65	2.98	0.67	54.48	−4.37	−3.00	−1.37	− 7.46	64.5	− 10.5
21	3.61	2.90	0.71	50.85	−2.55	−2.00	−0.55	− 2.80	60.9	− 4.8
22	3.60	2.89	0.71	50.70	−0.85	−1.00	+0.15	+ 0.76	60.7	− 0.2

Table II—Calculation of coordinates of points at which lines of rearward vision projected through screens *A* and *B* meet the ground.

to Fig. 4 and by similar triangles:

$$w/10 = a/(a-b)$$

therefore,

$$w = 10\ a/(a-b).$$

Since the eye mid-point E is 10 ft ahead of screen A,

$$z = w + 10.$$

Fig. 5 shows a plan view of screens A and B and the point R. Dimensions a' and b' represent the lateral distances from the plane of Fig. 4 to the points on the screens through which the line of vision passes. To determine the exact location of the first tabulated point read from screens A and B, it also is necessary to calculate the dimension t which is the lateral distance from the eye mid-point position E to the ground point R. Referring to Fig. 5 and using similar triangles:

$$v/(b' - a') = w\ /\ 10$$

therefore,

$$v = w\ (b' - a')\ /\ 10$$

and $\quad t = v + a'.$

The first set of tabulated points read from screens A and B listed the vertical height above the ground of points a and b as 3.59 ft and 2.86 ft, respectively. The values of dimensions a' and b' were given as 0.00 ft and +0.83 ft, respectively. Substituting these established values for a, b, a', and b' into the above equations for z and t gives:

$$z = 10 \times 3.59/(3.59 - 2.86) + 10 = 59.2 \text{ ft}$$

and

$$t = 49.2\ \ (0.83 - 0.00)/10 + 0.00 = 4.1 \text{ ft}.$$

The Cartesian coordinates of the ground point R for the first set of tabulated points read from screens A and B, therefore, are 59.2 ft behind the eye mid-point position E and 4.1 ft to the right of E. Table II gives the complete tabulation of rectangular coordinates necessary to plot the ground plan of driver rearward visibility. When all of the points have been plotted and connected, the ground plan for driver rearward visibility appears as in Fig. 6. The shaded area in Fig. 6 represents areas which cannot be seen by either eye of the driver unless he makes a head movement.

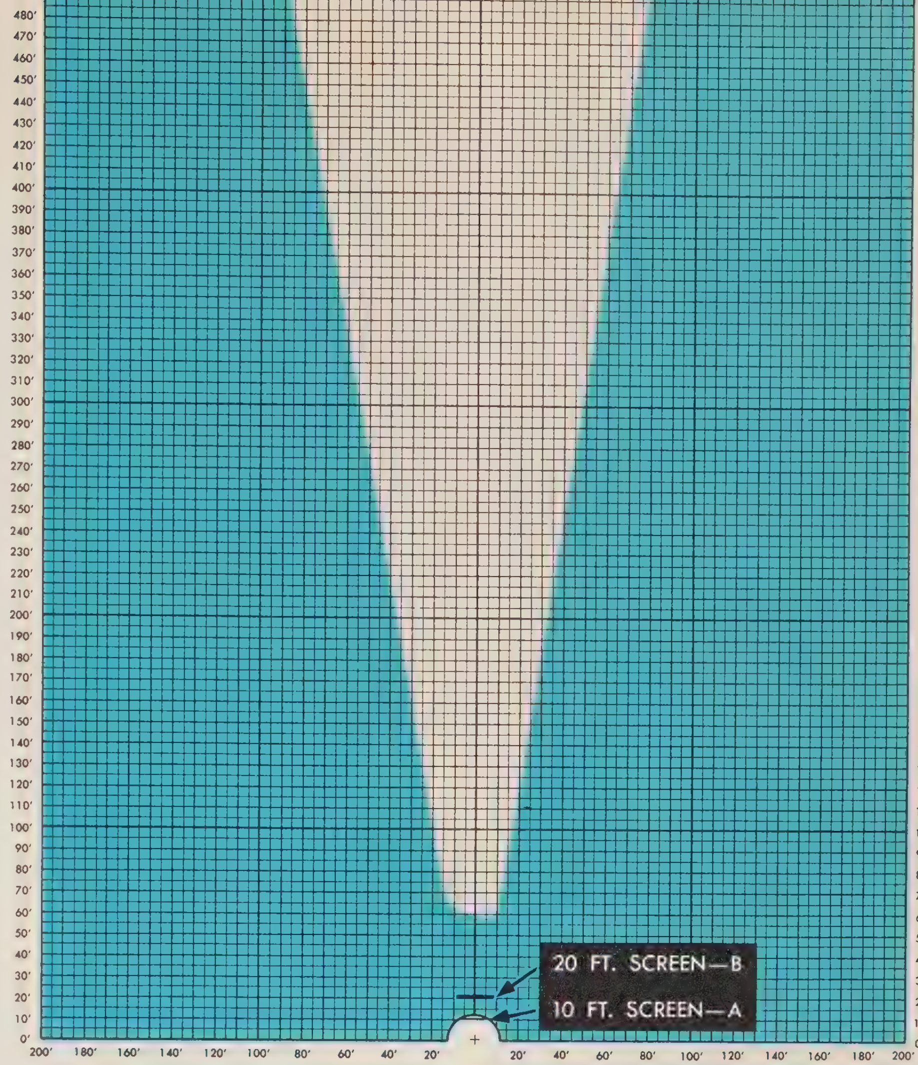


Fig. 6—Completed chart—Ground Plan of Driver's Vision—to the Rear.

Summary

The procedure used in solving the problem is a long and tedious one. In actual practice, plotting the ground plan for driver forward visibility is simplified greatly by two specially constructed instruments which enable the engineer to determine the distance to a point projected from screen F to the ground and to plot it directly, using polar coordinates, on charts similar to the one used in Fig. 3.

The developed ground plan for driver forward visibility shows that comparatively small areas of the ground are obscured from both eyes of the driver (Fig. 3). The ground can be seen at about 32½ ft straight ahead of the driver. The ground plan for driver rearward visibility shows the area which cannot be seen through the rear-view mirror (Fig. 6).

The street patterns superimposed upon the chart at minimum stopping distances for speeds of 30 mph and 60 mph illustrate the wide-angle positions where the obstructed area caused by windshield pillars becomes large enough to conceal another car, assuming that the driver does not change his eye position (Fig. 3). Continual development work in body engineering has reduced these obstructed areas.

The development of the pattern on screen F, as illustrated in the statement of the problem in the March-April 1954 JOURNAL, indicates the amount of forward visibility at eye level and above the horizon. This information is not shown on the ground plan. It reveals the angles to the right and left of straight ahead at which vision is obscured, and it also shows that the driver can see under the rear-view mirror.

Similarly, the development of screens A and B to the rear shows the shape of the rear-view pattern and indicates that the horizon cannot be seen through the rear-view mirror.

In this typical problem, the test data were developed for a person of average stature in a previous year's car model with the seat adjusted to its center position and carrying a typical load.

Development of the test-screen patterns and the ground plans provide another tool enabling automotive engineers and stylists to evaluate progress in visibility through the years and to select the optimum designs for future cars.

A Typical Problem in Automotive Design: Determine the Tensile Stress in Pump-Cover Bolts on a Torque-Converter Transmission

By ANTHONY J. PANE
Buick
Motor
Division

What are the forces affecting the bolts at 5,000 rpm?

Calculating the tensile stress in the bolts of a machine assembly to obtain a satisfactory design is a common problem in the work of an engineer. The analysis of the loads which produce the tensile stress, however, provides considerably more variety of calculation. In the design of a torque-converter-type transmission, for example, it is necessary to determine the tensile stress in the bolts which attach the cover to the outer casing of the converter pump or impeller. The problem requires an analysis of the longitudinal separating force at 5,000 rpm, due to the centrifugal pressure of the oil and the converter-charging pressure. The mathematical solution may be verified by graphical means. Both the graphical and mathematical solutions will be presented in the July-August 1954 issue of the JOURNAL.

A TYPICAL automobile automatic transmission of today utilizes a fluid torque converter, planetary gears, and hydraulic controls. These three principal components of the transmission work in conjunction with each other to produce the end result of eliminating the manual shifting of gears.

The fluid torque converter is composed of three vaned members—the driving member, called the pump; the driven member, called the turbine; and the stationary member, called the stator. The delivery of power from the car's engine to the rear wheels is initiated in the transmission by the centrifugal action of the pump. The pump, which is directly connected to the engine, drives the turbine through the medium of oil. The torque multiplication necessary to drive the car is brought about by the reactive force of the oil striking the stator blades after it leaves the turbine. The torque-multiplying characteristics of the planetary gears, working in conjunction with the torque-multiplying ability of the fluid torque converter, maintains a smooth, uninterrupted flow of power from the engine to the rear wheels.

The pump, which revolves with engine speed and is integral with the revolving oil-tight casing, is attached to the cover by means of bolts. As the converter assembly rotates, the centrifugal action of the rotating oil acting on the wall of the pump causes a *radial force*. The centrifugal pressure of the fluid acting on

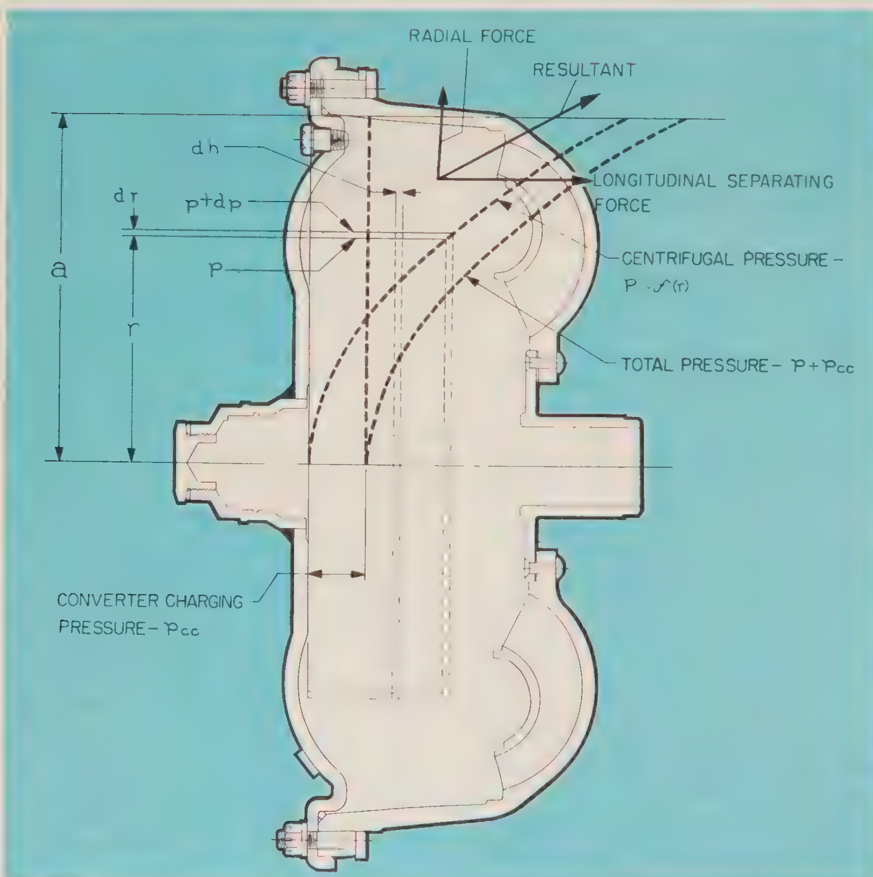


Fig. 1—View of the pump-cover assembly showing the force and pressure distribution during a high-speed spin. p_{cc} represents the converter-charging pressure; a represents the maximum radius of the pump torus (6 in.); p represents the centrifugal pressure in psi at radius r; dp represents the elemental increase in pressure p as radius r increases to $r+dr$; dh represents the elemental height of the ring of fluid of inner radius r and outer radius $r+dr$.

CONSTANT SPEED—5000 RPM	
Centrifugal Pressure p (psi)	**Radius r (inches)**
2.8	0.5
11.1	1.0
25.0	1.5
44.4	2.0
69.4	2.5
99.9	3.0
136.0	3.5
177.6	4.0
224.8	4.5
277.5	5.0
335.8	5.5
399.6	6.0

Table I—Values to be used in the graphical determination of the tensile stress in the pump-cover bolts on a torque-converter transmission.

the sides of the cover and pump will cause a *longitudinal separating force.* Both of these forces will affect the magnitude and direction of the resultant force. In this problem, consider only the longitudinal separating force and its effect on bolt tension. It is important that these tensile stresses be calculated so that the correct bolt size and the number of bolts can be selected for the required strength.

Problem

The problem is to calculate the tensile stress in the pump-cover bolts due to the longitudinal separating force which is caused by the centrifugal pressure of the transmission oil when the converter unit is rotating in a high-speed spin of 5,000 rpm.

Fig. 1 shows a view of the pump-cover assembly, the position of two of the bolts, and dimensions necessary to solve the problem. In the solution to the problem, neglect the bending stresses induced in the bolt because the line of action of the separating force is not coincident with the longitudinal axis of the bolt.

Given data necessary to calculate the tensile stress in the bolts are as follows:

- number of bolts = 15
- bolt specifications = $\frac{5}{16}$, 24 UNF (Class —2A, 0.2603-in. minor diameter)
- pump speed = 5,000 rpm
- pump-torus diameter = 12 in.
- converter-charging pressure = 60 psi
- density of transmission oil = 0.031 lb per cu in.

Additional information which will prove helpful in solving the problem is that, at any given speed N, the centrifugal pressure p will be a function of the instantaneous radius r. A suggestion, as to solution procedure, is to determine first how the centrifugal pressure of the oil increases radially towards the periphery of the pump.

A graphical solution to the problem is possible and also can be used to substantiate the answer obtained from the mathematical calculations. In Table I are values of centrifugal pressure at various radii and at a constant speed of 5,000 rpm. If the points are plotted, a curve will result which can be used to give a graphical solution. The accuracy of this type of solution will depend upon the accuracy with which the graph is drawn.

The graphical and mathematical solutions to the problem will appear in the next issue of the JOURNAL.

Recent Speaking Engagements Filled by GM Engineers

Engineer-lecturers, speaking in engineering classrooms and before technical societies and other groups, are but one facet of General Motors' continuous program aimed at making available information on GM engineering developments to interested persons outside the organization. Listed below are some of the recent speaking engagements of GM engineers.

Ralph E. Brown, assistant division engineer in the Product Engineering Department of Hyatt Bearings Division, spoke before the National Metal Trades Association on January 15 in New York City. His topic was "Hyatt Barrel Bearings."

Martin J. Caserio, chief engineer—automotive products, AC Spark Plug Division, Flint, Michigan, spoke on "Attitudes and Ideas as they Affect the Engineer" before the Rotary Club in Davison, Michigan, on February 4.

Walter Eitel, general supervisor of tool engineering and methods at AC Spark Plug, Flint, addressed the Supervision Conference held at Farrington Manufacturing Company in Boston, Massachusetts, on February 17. His topic was "The Foreman's Responsibility in Work Simplification."

On February 20, before the Flint Rotary Club, **Leonard E. Batz,** project engineer at AC Spark Plug in Flint, spoke on "Engineering—Past, Present, and Future."

Mr. Batz also addressed the Flint Shrine Club on February 23. His topic was "The Human Element in Engineering."

"Obtaining Employes' Acceptance of Methods Changes and Production Standards" was the title of the talk given by **Howard L. Roat,** master mechanic at AC Spark Plug, Flint, before the Grand Rapids Division of the Bureau of Industrial Relations meeting in Grand Rapids, Michigan, on March 2.

John A. McDougal, engineer—military products, AC Spark Plug, Flint, described "The T-38 Fire Control System" to the West Flint Kiwanis Club on March 9.

Harry W. Lisiak, chief process engineer at AC Spark Plug, Milwaukee, Wisconsin, completed two speaking engagements during February. On February 4 he addressed the Vocational Guidance Group of the Pius XI High School in Milwaukee outlining "Scientific Research."

On February 11, Mr. Lisiak spoke to the graduating class of Marquette University High School, Milwaukee on "Science for the Next 100 Years."

William M. Knight, senior project engineer at AC Spark Plug, Milwaukee, discussed "Aeronautical Engineering" before the student body of Piux XI High School, Milwaukee on February 20.

P. G. Jackson, supervisor of the Chemical Section of the Metallurgical Department, Allison, spoke to the Indianapolis Chapter of the American Chemical Society on February 9 in Indianapolis. His topic was "Industrial Waste Control."

The topic "Engineering of Hydraulic Transmissions" was the subject of several speaking engagements filled by various engineers of the Transmission Engineering Department, Allison Division, Indianapolis, Indiana.

The engineers presenting these talks were as follows:

H. C. Kirtland, chief engineer, Applications Group, before a group of mechanical engineering students at Drexel Institute of Technology, Philadelphia, Pennsylvania, on January 21; also before the Student Chapter, S.A.E., Michigan State College, East Lansing on February 10.

B. F. Hartz, application engineer, before a joint meeting of the Student Chapters of A.S.M.E., A.I.E.E., A.S.C.E., and A.I.Ch.E. at Vanderbilt University, Nashville, Tennessee, on February 3.

R. M. Tuck, supervisor of design engineering, before the Student Chapters of A.S.M.E., S.A.E., I.A.S., and A.I.E.E. at University of Oklahoma, Norman on February 17.

R. M. Schaefer, manager of transmission engineering, before the Student Chapters of A.S.M.E., S.A.E., and

A.I.E.E. at University of Illinois, Urbana on February 17.

C. V. VonLinsowe, products engineer, before the Student Chapters of S.A.E. and A.S.M.E. at Case Institute of Technology, Cleveland, Ohio, on February 23.

J. A. Winter, supervisor of technical data, before the Student Chapters of A.S.M.E. and S.A.E. at Rose Polytechnic Institute, Terre Haute, Indiana, on February 25.

H. W. Christensen, chief research and development engineer, before mechanical engineering students at Kansas State College, Manhattan on March 4.

J. E. Storer, chief products engineer, before the Student Chapter of A.S.M.E. at University of Kentucky, Lexington on March 11.

Roger E. Mitchell, master mechanic at Buick Motor Division, spoke to the Saginaw Valley Chapter of the A.S.T.E. at the Buick V-8 Engine Plant, Flint, Michigan, on February 18. His topic was "Processing the 'V' Engine."

Kenneth A. Meade, director of the Educational Relations Section, Department of Public Relations, Central Office, spoke March 18 before the Genessee Valley Chapter of the American Society of Tool Engineers on the subject "The Engineer and His Profession." The meeting was held at General Motors Institute in Flint, Michigan.

On February 23 at University of Illinois in Chicago, **Arthur P. Siewert,** chief metallurgist in the Laboratory at Central Foundry Division, appeared before the American Society for Engineering Education discussing "Metallurgy in the Production of Cast Iron."

"The Corvette Plastic Body" was discussed by **C. C. Jakust,** design engineer in the Chief Passenger Body Design Group of Chevrolet Motor Division, at the meeting of the Cincinnati, Ohio, Section of the S.A.E. on January 25. Mr. Jakust also spoke on the same subject on March 19 in Columbus, Ohio, before a joint meeting of the Central Ohio Section—Society of Plastics Engineers and the Columbus-Dayton Section of the S.A.E.

This same subject was discussed by **E. J. Premo,** assistant chief engineer-in-charge of the Passenger Car and Truck Body Design Group of Chevrolet Motor, before the Chicago Section of the Society of the Plastics Industry on February 4.

On February 9 Mr. Premo appeared before the New York Metropolitan Section of the S.A.E. in New York City. His topic was "What Is the Place of Fiberglas Plastic or Other Synthetic Materials in the Building of Sports Cars?"

Maurice Olley, director of the Research and Development Section at Chevrolet Motor, spoke before the New York Metropolitan Section of the S.A.E. on February 9. His topic was the "Evaluation of Suspensions and Comfort for Sports Cars."

G. C. Aitken, assistant staff engineer-in-charge of the Drafting Room at Chevrolet Central Office, spoke before the Milwaukee Group of the Society of Plastics Engineers on February 9. His topic was "The Corvette Plastic Body."

"Automotive Power—Gas Turbine or Piston Engines" was the talk given before the American Petroleum Institute, Division of Marketing, Lubrication Committee, in Detroit, Michigan, on February 17 by **M. M. Roensch,** director of laboratory tests in the Test Group of Chevrolet Motor.

Before the General Electric Engineering Club, Syracuse, New York, on February 18, **Maurice Olley,** director of the Research and Development Section, Chevrolet Motor, spoke on "The Evolution of a Sports Car—The Chevrolet Corvette." Mr. Olley spoke again on this subject on March 22 at Case Institute of Technology, Cleveland, Ohio, before a joint meeting of the Cleveland Section and the Student Branch of the S.A.E.

J. G. Coffin, assistant metallurgical engineer in the Production Engineering Group of Chevrolet Motor, appeared before the Pacific Coast Section of the Society of the Plastics Industry on March 11 in Coronado, California. His topic was "The Corvette Plastic Body."

W. S. Wolfram, assistant staff engineer in the Research and Development Section of Chevrolet Motor, spoke before the Wilmington Section and the Student Branch of the A.S.M.E. at University of Delaware in Newark. The title of his talk, given on March 17, was "The Evolution of a Sports Car—the Chevrolet Corvette."

B. A. Schwarz, chief engineer at Delco Radio Division, addressed the Collins Radio Technical Association, Cedar Rapids, Iowa, on March 2. His topic was "A Glimpse of Industry Putting America on Wheels."

"Transistors in the Electronics of Tomorrow" was the subject discussed by **James H. Guyton,** assistant chief engineer, electrical, at Delco Radio, before the Police Communication Association of Kokomo, Indiana, on March 18.

"Evolution of the Hydra-Matic Automatic Transmission" was the title of the talk given by **Kenneth W. Gage,** chief engineer in the Product Design Department of Detroit Transmission Division. The appearance was before the Livonia, Michigan, Rotary Club on February 15.

Hans M. Gadebusch, fuels and lubricants engineer at Detroit Diesel Engine Division, spoke at University of California, Los Angeles on February 12. His topic was "Should Diesel Engine Lubricating Oil be Color-Clean?"

At the S.A.E. Passenger Car Meeting held in Detroit, Michigan, on March 2, **Paul Vermaire,** senior engineer in the Product Engineering Department of Diesel Equipment Division, in conjunction with **J. B. Bidwell,** assistant head of the Mechanical Development Department of the Research Laboratories Division, presented a paper entitled "Lifters and Lubricants."

On February 11 in Peoria, Illinois, before the Central Illinois Section of the S.A.E., **L. Petersen,** chief structural engineer in the Engineering Department of Electro-Motive Division, discussed "The Application of the Engineering Test Car to Stress Analysis in the Field."

Charles A. Chayne, vice president in charge of the General Motors Engineering Staff, addressed the Rotary International in Miami, Florida, on February 4. His topic was "General Motors and Competition."

Howard K. Gandelot, engineer-in-charge of the Vehicle Safety Section of the GM Engineering Staff, GM Technical Center, outlined "Automobile Design—Past and Present" to the Paul Hickey Class of the Metropolitan Methodist Church, Detroit on February 9.

C. H. Jensen, manager-in-charge of the Parts Fabrication Group of the GM

Engineering Staff, GM Technical Center, appeared before the Executive Club of the Bethlehem Steel Corporation on February 17. His topic was "The Use of Laminated, Reinforced Plastics in Experimental-Body Construction."

Max Ruegg, suspension engineer in the Stucture and Suspension Development Group, GM Engineering Staff, GM Technical Center, described "Laboratory Simulation of Car Shake" before the 1954 National Passenger Car, Body, and Production Meeting of the S.A.E. held in Detroit, Michigan, on March 4.

"Administration of Methods Engineering Functions" was the title of the talk given on November 19 at Wayne University, Detroit by **J. F. Banocy**, supervisor of the Tool Planning and Production Engineering Department of Fisher Body Division.

S. Commer, process engineer in the Tool Planning Department of Fisher Body, addressed a Wayne University class in Detroit on February 11. His topic was "Automation."

E. J. Opitz, senior engineer-in-charge of the Product Engineering Section, Design Activity of Fisher Body, appeared before the American Society of Body Engineers in Detroit on February 18. The topic of his talk was "Automobile Body Development as Seen by a Tool Engineer."

On March 8 Mr. Opitz addressed the National Association of Engineering Companies at Detroit, discussing the subject, "Facts and Reflections in Regard to 'Outside' Engineering."

Orlo L. Crissey, chairman of the Personnel Evaluation Service Department at General Motors Institute, spoke on "The Research Approach to the Evaluation of Training" before the Industrial Training Council for the State of New York. The meeting was held in Rochester, New York, on February 18.

On January 13 **Kenneth A. Stonex**, head of the Technical Data Department at the General Motors Proving Ground, Milford, Michigan, discussed the "Relation Between the Automobile and the Highway" at the 33rd Annual Meeting of the Highway Research Board held in Washington, D. C.

David C. Apps, head of the Noise and Vibration Laboratory, GM Proving Ground, Milford, Michigan, appeared before the Battle Creek Engineers' Club on February 23. His topic was "The General Motors Proving Ground."

On February 2 over Station WKAR-TV, located at Michigan State College, East Lansing, **T. J. Carmichael**, administrative engineer at the GM Proving Ground, Milford discussed "Safe Winter Driving."

At the Ninth Annual Butler County Regional Safety Conference held on March 2 in Hamilton, Ohio, Mr. Carmichael outlined "Built-In Automobile Safety."

Louis C. Lundstrom, assistant director of the GM Proving Ground, Milford described the "General Motors Proving Ground" to the Collins Radio Technical Association meeting in Cedar Rapids, Iowa, on March 2.

Before the Erie, Pennsylvania, Section of the American Society of Refrigerating Engineers on February 8, **E. M. Estes**, body engineer in the Product Engineering Department of Oldsmobile Division, described "Oldsmobile Air Conditioning for 1954."

R. H. Whiters, plant layout supervisor in the Methods and Plant Layout Department of Oldsmobile, appeared before the plant-layout class in the Engineering School, Michigan State College in East Lansing. The topic of his talk, given on March 9, was "Plant Layout at Oldsmobile."

"Structural Properties Needed to Suppress Car Shake" was the title of the talk given by **Mark J. Garlick**, experimental engineer at Pontiac Motor Division, before the S.A.E. National Passenger Car Body and Materials Meeting held in Detroit from March 2 through 4.

Paul A. Bennett, research engineer in the Fuels and Lubricants Department of the Research Laboratories, spoke before the S.A.E. in Cleveland, Ohio, on January 18. The title of his talk was "The Relative Importance of 'Knock' and Auto-Ignition in Determining the Octane Requirement of Passenger Cars."

C. F. Nixon, head of the Electro-Chemistry Department of the Research Laboratories, appeared before the American Electroplaters Society meeting at Pittsburgh, Pennsylvania, on February 3. The title of his talk was "Decorative Plating on Automobiles."

At the February meeting of the American Society for Testing Materials held in Washington, D. C., **Roger Saur**, senior physicist in the Physics and Instrumentation Department of the Research Laboratories, presented the paper "The Photochemical Deterioration of Automobile Lacquers."

At the International Combustion Symposium held at University of Pittsburgh on March 1, **William G. Agnew**, senior engineer in the Fuels and Lubricants Department of the Research Laboratories, in conjunction with John T. Agnew and Kenneth Wark of Purdue University, discussed "Infrared Emission Spectra of Radiation from Stabilized Cool Flames and Motor-Engine Cool Flame Reactions."

During the Fifth Annual Conference on Analytical Chemistry and Applied Spectroscopy held in Pittsburgh, Pennsylvania, from March 1 to 5, five Research Laboratories personnel presented papers. **Antrim H. Jones**, research chemist in the Chemistry Department, delivered "An Indirect Method for the Determination of Aluminum in a Zinc Alloy, Using 8-Hydroxyquinoline."

During the same Conference, **Robert E. Kohn**, research chemist in the Chemistry Department, presented the paper "The Simultaneous Determination of Chromium and Manganese in Steels and Cast Iron—A New Approach."

Other speakers were **David L. Fry**, supervisor of the Physics and Instrumentation Department, **Thomas P. Schreiber**, and **J. L. Rembowski**, research physicist and college graduate-in-training, respectively, in this same Department, presented the paper "The Establishment of a Universal Quantitative Spectrographic Method for the Analysis of Low-Alloy Steel."

At the S.A.E. meeting held in Detroit on March 2, **Ralph J. Wirshing**, head of the Chemistry Department, Research Laboratories, delivered the talk "Lacquer as a Finish on Automobiles."

Charles A. Amann, senior research engineer in the Gas Turbine Department, Research Laboratories, addressed the Junior Section of the Society of Automotive Engineers in Detroit on March 15. His topic was "Thermodynamics—A Key to the Future of the Automotive Gas Turbine."

Howard W. Brandt, general manager of Rochester Products Division, appeared before the S.A.E. in Rochester, New York, on February 17. The title of his talk was "Education and Industry, Are We on Common Ground?"

Mr. Brandt later spoke to the S.A.E. in Flint, Michigan, on "Carburetion."

Progress Reports from GM Locations

Complex Shapes of Jet-Engine Blades Produced with Aid of Special Techniques

The mass production of jet-engine blades is one of the most critical, complex, and exacting of industrial tasks. Some jet-engine blades have forty different dimensions and are neither round nor square, flat nor curved, triangular nor rectangular—but a combination of all these shapes. Frigidaire Products of Canada, Limited, a General Motors subsidiary, has developed special techniques and machines to permit the most economical and quickest manufacturing methods, while still assuring that each blade is produced to exact specifications. A foil checking device, operated by a vacuum, probes eighteen dimensions at once and checks their accuracy to 0.001 in. Readings are taken from tubes in which different levels of colored liquids represent the thickness of the trailing and leading edges, the angular displacement, and other dimensions. Another checking device, called a comparator, is equipped with a lighted screen on which a magnified image of a stylus point, tracing an engine-blade's outline, is thrown against a big master chart to expose instantly any inaccuracies.

Vehicle Proving Facility Opened at Pikes Peak

General Motors has developed a third geographical area of proving operations, this one at Pikes Peak. The Engineering Test Headquarters established at Manitou Springs, Colorado, supplements the vehicle-testing facilities maintained at the Commercial and Military Proving Ground, Milford, Michigan, and at the Desert Proving Ground near Mesa, Arizona.

The Pikes Peak roadway is regarded as ideal on which to test engines, automatic transmissions, carburetors, brakes, and cooling systems under conditions of extreme altitude and grade. The road has a maximum grade of 10.5 per cent, with an average of 7 per cent, and rises 6,686 ft in the 18 miles from its start at Cascade to the peak which is 14,110 ft above sea level.

The facilities will be used by all five GM car Divisions, as well as the truck operations of Chevrolet Motor Division, Detroit Transmission Division, Research Laboratories Division, and the Transmission Development Group of the GM Engineering Staff.

Thermocouple Principle Enables New Tool to Sort Identical Metal Objects of Different Composition

The Research Laboratories Division has announced the development, in its Physics and Instrumentation Department, of a rapid, accurate, non-destructive, portable instrument employing electric detection for use as a tool to sort mixed, identical, metal parts of varying alloy content. The portable instrument—known as the Thermoelectric Metal Comparator—is operable in any surroundings as a trouble shooter to distinguish parts in which material composition is the only discriminating feature.

The functions of this versatile new comparator are fourfold:

- To restore order wherever parts have been scrambled inadvertently in storage
- To detect chills, which cause hardness in castings
- To measure thickness of paint films and metallic plating
- To supplement or supplant the conventional methods of analysis—chemical, spectrographic, magnetic, and spark-plug testing—in production.

The comparator operates on the thermocouple principle which uses a circuit consisting of a loop of two different metals. In this application of the principle, the part being tested forms a portion of the loop or circuit. The instrument has two probe tips which serve as the hot and cold junctions where they contact the metal being tested. Since the temperatures of the two junctions remain constant, the change in metallic composition of the part under test results in a voltage change which can be read on the instrument's meter. Because only a small voltage occurs—as a result of the small difference in temperature between the two tips—an amplifier is included to create a quick response-time indicator for increased sensitivity.

Selection of probe tips made of many types of alloys thus adapts the comparator to a variety of problems. A trial testing will determine a correct type for a particular usage. It is possible also to make a special set of tips to suit any unique testing requirements.

By touching the instrument's probe to the part, an immediate dial reading is obtained comparing the composition of one part with another. This enables the instrument to be used on the spot by an operator without any special skill.

In its tryout stage, the comparator averted a threatened production-line stoppage in one General Motors Division by singling out from a mixed stock the critical steel needed. These steels differed only 0.05 per cent in carbon content.

Jet-Engine Performance Tested by Engineers Atop Mt. Washington

Engineers try to test equipment under the eventual operator's actual conditions. Each fall Allison Division sends stock jet engines and a group of engineers to the U. S. Air Force-Navy test facility on the 6,280-ft summit of Mount Washington in the White Mountains of New Hampshire, where the wind reaches a record velocity of 231 mph and the temperature frequently drops to 48° F below zero. These extreme conditions provide a natural proving ground to determine the reactions of jet engines and engine components to severe wind and icing conditions. The equipment is set up in the autumn and remains until the ground thaws out in the spring. During the winter, engineers try out various methods of operation, keeping close records and taking photographs periodically. Engineers claim that if jet engines can be operated satisfactorily under the conditions found on Mount Washington, they will operate in any icing atmospheric conditions in the world.

Contributors to May-June 1954 Issue of

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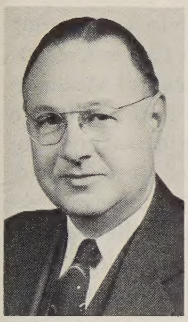
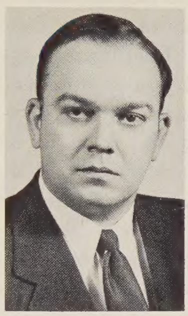


C. F. ARNOLD, contributor of "The Interrelationship of Styling and Basic Chassis Design," joined Cadillac Motor Car Division as a laboratory assistant and earned successive promotions to his present position as chief engineer. His earlier job assignments took him into the manufacturing and service operations where, with his basic engineering viewpoint, he gained direct experience in wide fields of the Division's work.

Mr. Arnold earned his B.S.M.E. degree at University of Cincinnati where he graduated in June 1923, and two years later joined Cadillac. An early assignment on engine-vibration problems led to the development of a patented flexibly mounted flywheel for dampening crankshaft vibrations, one of the eight inventions resulting from his work. In 1934 he became supervisor of the Engineering Laboratory, responsible for engineering tests on all parts of the car. He was transferred in 1938 to the Service Section of the Sales Department as an engineer who studied customers' complaints and followed corrective measures through the affected Departments. Then he moved into Manufacturing Department in a technical liaison capacity between the service-engineering function and production.

In 1943, when Cadillac was completely in war production, Mr. Arnold returned to the Engineering Department as head of the newly formed Research and Development Section. In addition to consolidating and organizing all research and product-development activities under one head, he had charge of the technical development work on the M-24 series of track-laying vehicles and other military equipment. By June 1946 Mr. Arnold had also been instrumental in the planning of a complete new laboratory as part of the modernization of the whole Research and Development Section. At that time he was appointed assistant chief engineer and in January 1950, when the 1954 model planning was just starting, he became chief engineer.

Mr. Arnold's current paper is an outgrowth of a talk given before the Engineering Society of Cincinnati in November 1953. He is a member of the Society of Automotive Engineers and has served on its Passenger Car Activity Committee.



EUGENE W. CHRISTEN, contributor of this issue's "Notes About Inventions and Inventors," serves as patent attorney in the Patent Section of the Central Office Staff, Detroit.

Purdue University granted Mr. Christen the B.S.M.E. degree in 1948. He began his patent work with General Motors in July of the same year as a patent searcher in the Washington, D. C. office of the Patent Section. While there he continued his studies at Georgetown University and was granted the L.L.B. degree by that institution in 1951. Shortly afterward he transferred to the Dayton, Ohio office of the General Motors Patent Section as a patent attorney. In January 1952 he transferred to his present location.

Of particular concern to Mr. Christen as a patent attorney are those patent matters dealing with gas turbines, free piston engines, and automobile bodies. As a member of the Patent Section, he shares the Section's responsibility of furnishing necessary patent protection for new apparatuses and processes developed by General Motors employes, of advising engineering organizations on patent matters, and of negotiating royalty arrangements with non-GM companies.

Mr. Christen served in the Air Transport Command as an aircraft engineering officer from January 1943 through August 1946. He separated with the rank of captain.

Mr. Christen is a member of the bar of the District of Columbia and is a registered patent attorney.

JAMES D. LESLIE, contributor of "Solving the Design and Development Problems of Automobile Door Locks," has served since 1945 in the Engineering Department of Fisher Body Division, Detroit, first as a senior designer and since 1947 as a senior project engineer. Currently, much of his time is devoted to development work on body hardware and ventilation. One of his recent projects was the shroud ventilation system for some 1954 models of GM cars.

Other engineering projects at Fisher Body have included guided-missile components, weather strips, glass channels, window regulators, and door locks, a field in which his work has resulted in a patent. Mr. Leslie was a Ternstedt Division methods engineer from June 1939 to 1941, concerned at various times with operation analysis, cost and waste-reduction studies, labor balance, plant layout, and conducting methods conferences for plant personnel. During World War II, he served with the DeSoto Division of Chrysler Corporation, successively as a tool engineer, chief tool engineer, and assistant master mechanic. In the latter capacity he was in charge of tool and die processing and design and tryout on a variety of manufacturing jobs for aircraft, tank guns, and trucks.

Mr. Leslie received the B.M.E. degree from University of Detroit in 1939, having attended under the cooperative engineering program as a student engineer in the Research Laboratories of Detroit Edison Company. As a student, he earned Tau Beta Pi honors and later was elected to Delta Theta Phi, law honorary, while studying at the Detroit College of Law. He currently represents Fisher Body Division on the GM Technical Subcommittees for Car Air Conditioning and Car Heating and is chairman of the Car-Ventilation Subcommittee. He also is a member of the Society of Automotive Engineers.

FRANCIS J. MARKEY, contributor of "The Chemical and Physical Properties of Brake Fluids for Safe Vehicle Operation," serves as a product engineer at Moraine Products Division, Dayton, Ohio.

Mr. Markey's entire engineering career has been with General Motors in various capacities related to brakes, fluids, and brake applications. He began in 1931 as an assembly repairman at Delco Products Division and was promoted to brake engineer. Starting in 1935 at Delco Brake Division (which subsequently merged with Moraine Products Division), he became laboratory head and advanced through several positions as production engineer, each having increasing responsibilities for various products. He was appointed to his present position in 1952.

As product engineer, Mr. Markey's duties include cooperating with the Production and Inspection Departments to assure that the brake-component products are produced as designed and that they meet the performance tests prescribed by the Engineering Department. He also supervises any proposed changes that are submitted as a result of field-service reports or employe suggestions. Other duties include field-service contacts, development of material specifications, and product studies. In addition, Mr. Markey is on a special-assignment status which includes assisting the Sales and Service Departments on promotional and educational work and he assists the Legal Department as an engineering consultant on brakes.

Ohio State University granted Mr. Markey the B.M.E., B.I.E., and M.S. degrees in 1931. He is a member of Tau Beta Pi and Texnikol.

Mr. Markey is a frequent contributor to the technical literature. His current paper is adapted from a previous paper on brake fluids published in the March 1953 *Journal of the Society of Automotive Engineers.*

Mr. Markey is a registered professional engineer and is a member of the Engineers Club of Dayton. He serves on the joint A.S.T.M. and S.A.E. Brake Cup and Boot Committee. In addition, he is chairman of the S.A.E. Brake Fluid Committee and a member of the S.A.E. Brake Committee.

WILBUR H. PFEIFFER, contributor of "Porcelain Enamel: Its Use and Manufacture for Household Appliances," is head of the Finishes Section of the Materials and Process Engineering Laboratory, Frigidaire Division, Dayton, Ohio. In this position, which he has held since 1935, Mr. Pfeiffer has charge of development of materials and processes. He also directs the technical work on problems in the production processes for painting and porcelain enameling, the subject of his paper in this issue.

His career in the ceramic industry began following his graduation from University of Illinois in 1924 with the degree of Bachelor of Science in ceramic engineering. He was appointed special research assistant to work in a sponsored investigation of refractories in the Department of Ceramic Engineering at University of Illinois. Upon completion of this assignment nearly three years later, Mr. Pfeiffer was employed as a research engineer on ceramic-bonded abrasives. In 1928 he joined General Motors as a ceramic engineer in the Engineering Department of Frigidaire Division. One of his early duties was to establish a laboratory for porcelain-enamel research. This laboratory continues in existence today as a part of the Finishes Section of the Materials and Process Engineering Laboratory at Frigidaire. In addition to the Finishes Section, this laboratory includes the Chemical, Metallurgical, and Process Specification Sections.

Mr. Pfeiffer's contributions to his profession have included membership in the American Ceramic Society where he has served on numerous committees, presented technical papers, and was elected chairman of the Society's Enamel Division in 1940. He is current chairman of the Annual Shop Practices Forum of the Porcelain Enamel Institute where he also has served on the Committee on Standardization of Tests for Products and has been active on other committees. In the National Electrical Manufacturers Association, he is a member of the Committee on Standard White Color for Major Home Appliances. He is a member of Keramos, a professional ceramic engineering fraternity.

PAUL L. VERMAIRE, contributor of "The Design, Development, and Manufacture of Hydraulic Valve Lifters" is senior engineer in the Engineering Department of Diesel Equipment Division, Grand Rapids, Michigan. Since his appointment to this position in 1951, his design projects have been concerned principally with hydraulic valve lifters, the subject of his current paper.

Mr. Vermaire has been with Diesel Equipment since 1944 when he was sponsored by this Division as a cooperative student at General Motors Institute. He had previously joined General Motors in September 1943 at the Grand Rapids plant of Fisher Body Division, following one year as a student at Calvin College.

He received the Bachelor of Mechanical Engineering degree from G.M.I. in 1949. While completing his undergraduate program, he fulfilled various work assignments at Diesel Equipment, including senior detailer. Following his graduation he was made junior engineer in the Engineering Department. One year later he was promoted to project engineer, which position he held until advancement to his present position.

One patent for an exhaust-valve rotator using a coil spring to effect progressive rotation has been granted, based on work conducted jointly by Mr. Vermaire and Morris V. Dadd, junior engineer at Diesel Equipment.

The technical society activities of Mr. Vermaire have included joint authorship (with Joseph B. Bidwell, assistant head, Mechanical Development Department, Research Laboratories Division) of a paper, "Lifters and Lubricants," presented to the Society of Automotive Engineers in March 1954. In addition, he serves as vice chairman of Grand Rapids for the Western Michigan Section, Society of Automotive Engineers. He is a member of Alpha Tau Iota, G.M.I. honorary fraternity.

Contributors' backgrounds vary greatly in detail but each has achieved a technical responsibility in the field in which he writes.

Faith of the Engineer

I AM AN ENGINEER. In my profession I take deep pride, but without vainglory; to it I owe solemn obligations that I am eager to fulfill.

As an Engineer, I will participate in none but honest enterprise. To him that has engaged my services, as employer or client, I will give the utmost of performance and fidelity.

When needed, my skill and knowledge shall be given without reservation for the public good. From special capacity springs the obligation to use it well in the service of humanity; and I accept the challenge that this implies.

Jealous of the high repute of my calling, I will strive to protect the interests and the good name of any engineer that I know to be deserving; but I will not shrink, should duty dictate, from disclosing the truth regarding anyone that, by unscrupulous act, has shown himself unworthy of the profession.

Since the Age of Stone, human progress has been conditioned by the genius of my professional forebears. By them have been rendered usable to mankind Nature's vast resources of material and energy. By them have been vitalized and turned to practical account the principles of science and the revelations of technology. Except for this heritage of accumulated experience, my efforts would be feeble. I dedicate myself to the dissemination of engineering knowledge, and especially to the instruction of younger members of my profession in all its arts and traditions.

To my fellows I pledge, in the same full measure I ask of them, integrity and fair dealing, tolerance and respect, and devotion to the standards and the dignity of our profession; with the consciousness, always, that our special expertness carries with it the obligation to serve humanity with complete sincerity.

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